SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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Activated Sludge Cultures—Engelbrecht and McKinney

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1957 ANNUAL INDEX

DECEMBER, 1957—VOL. 29, No. 12

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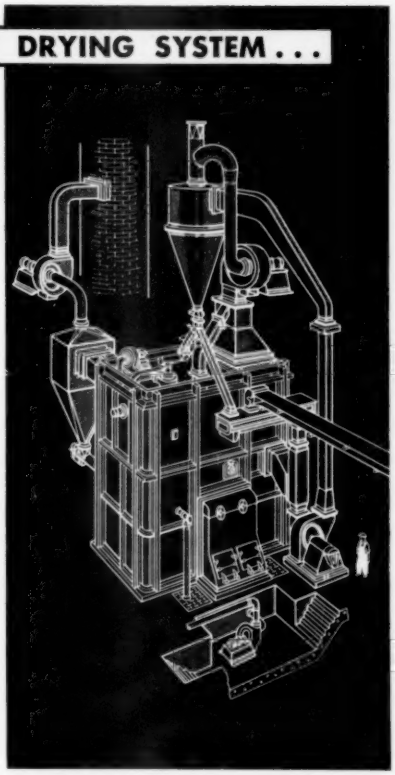

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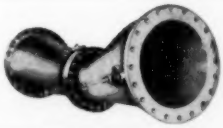
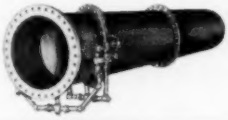
SMALL FLOWS OF WATER, GASES CORROSIVE FLUIDS		TYPE TF—MINIATURE VENTURI TUBES Machining to .0005" assures accuracy. Main diameters as low as ½"; throat diameters down to .1". Welded stainless steel models for high pressures. BROCHURE
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VTJ—SINGLE TAP VENTURI TUBES Single taps at main and throat have bayonet-type valve for fast cleaning. Absence of pressure belts prevents clogging. Inspection opening at throat. BULLETIN 005
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VS—FOUR TAP VENTURI TUBES Four cleaning valves at main and throat can be operated manually, by air, or hydraulically to keep piezometer holes clear for top accuracy. Two hand holes on each pressure belt and inspection opening at throat. BULLETIN 005
LOW-VELOCITY SEWAGE, HEAVY WASTES		TYPE VE—ELLIPTICAL VENTURI TUBES Developed specifically to accurately measure low-velocity sewage, sludge and heavy trade wastes—under low pressures. *Flat top* prevents air binding. *Flat bottom* is self-scouring. Inspection opening at throat. BROCHURE
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New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza New York City, N. Y.	Jan. 22–24, 1958
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 12–14, 1958
Montana Sewage and Industrial Wastes Assn.	Florence Hotel Helena, Mont.	Mar. 20–22, 1958
Arkansas Water and Sewage Conf.	University of Arkansas Fayetteville, Ark.	Mar. 24–26, 1958
Virginia Industrial Wastes and Sewage Works Assn.	Hotel Roanoke Roanoke, Va.	Apr. 28–29, 1958
Alabama Water and Sewage Assn.	Ala. Polytechnic Inst. Auburn, Ala.	June 9–11, 1958
Ohio Sewage and Industrial Wastes Treatment Conf.	Commodore Perry Hotel Toledo, Ohio	June 18–20, 1958
Michigan Sewage and Industrial Wastes Assn.	Charlevoix Hotel Charlevoix, Mich.	June 23–25, 1958

THIRTY-FIRST ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
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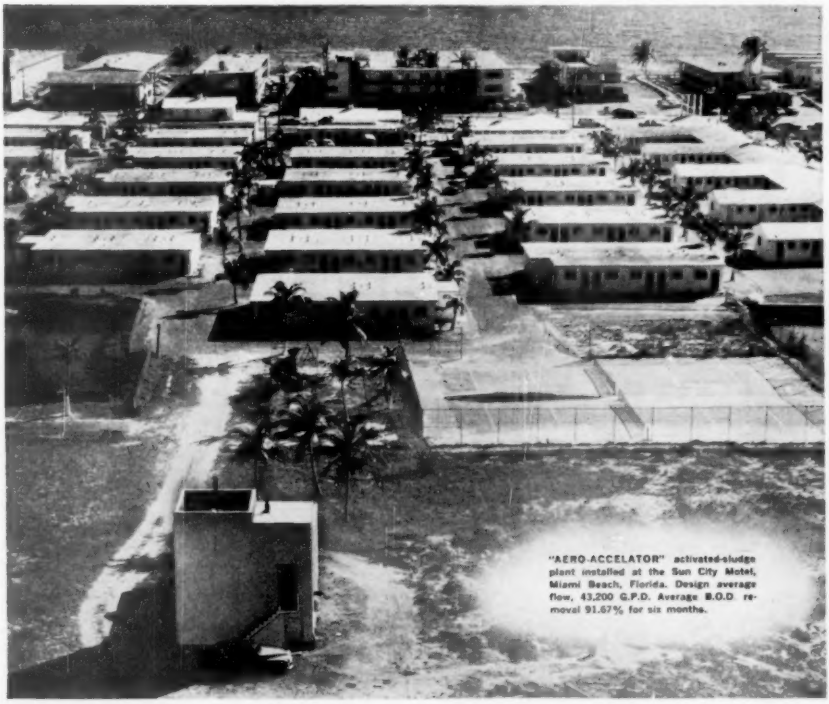

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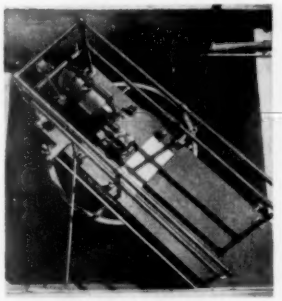
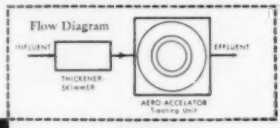
Month	Ave. Flow M.G.D.	B.O.D.P.P.M.			Suspended Solids — P.P.M.		
		Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal	Raw Sewage	"AERO-ACCELATOR" Effluent	% Removal
Jan.	.006	187	9.5	94	239	24	90
Feb.	.010	157	13.0	92	409	32	92
Mar.	.005	137	7.0	95	383	28	93
Apr.	.006	211	25.0	88	328	38	89
May	.006	171	9.0	94	222	5	97
June	.008	173	8.0	95	295	32	89



"AERO-ACCELATOR" unit



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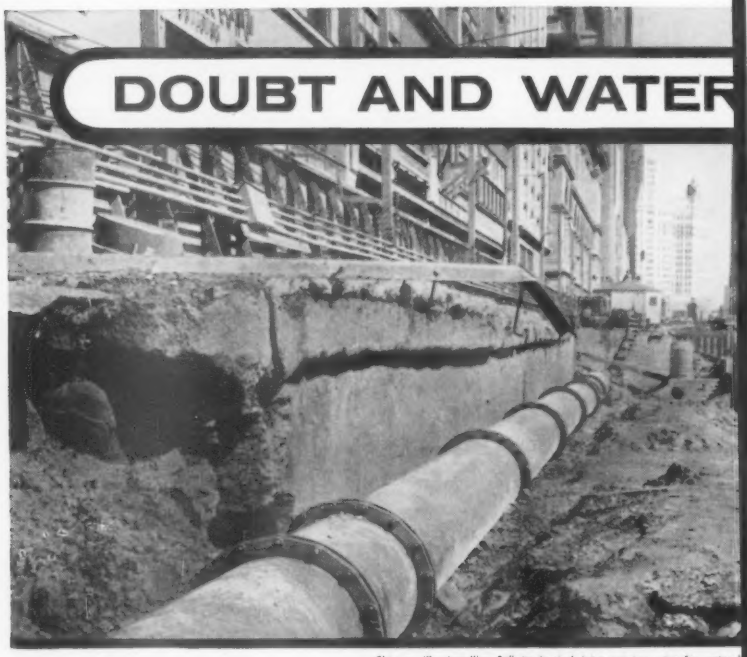

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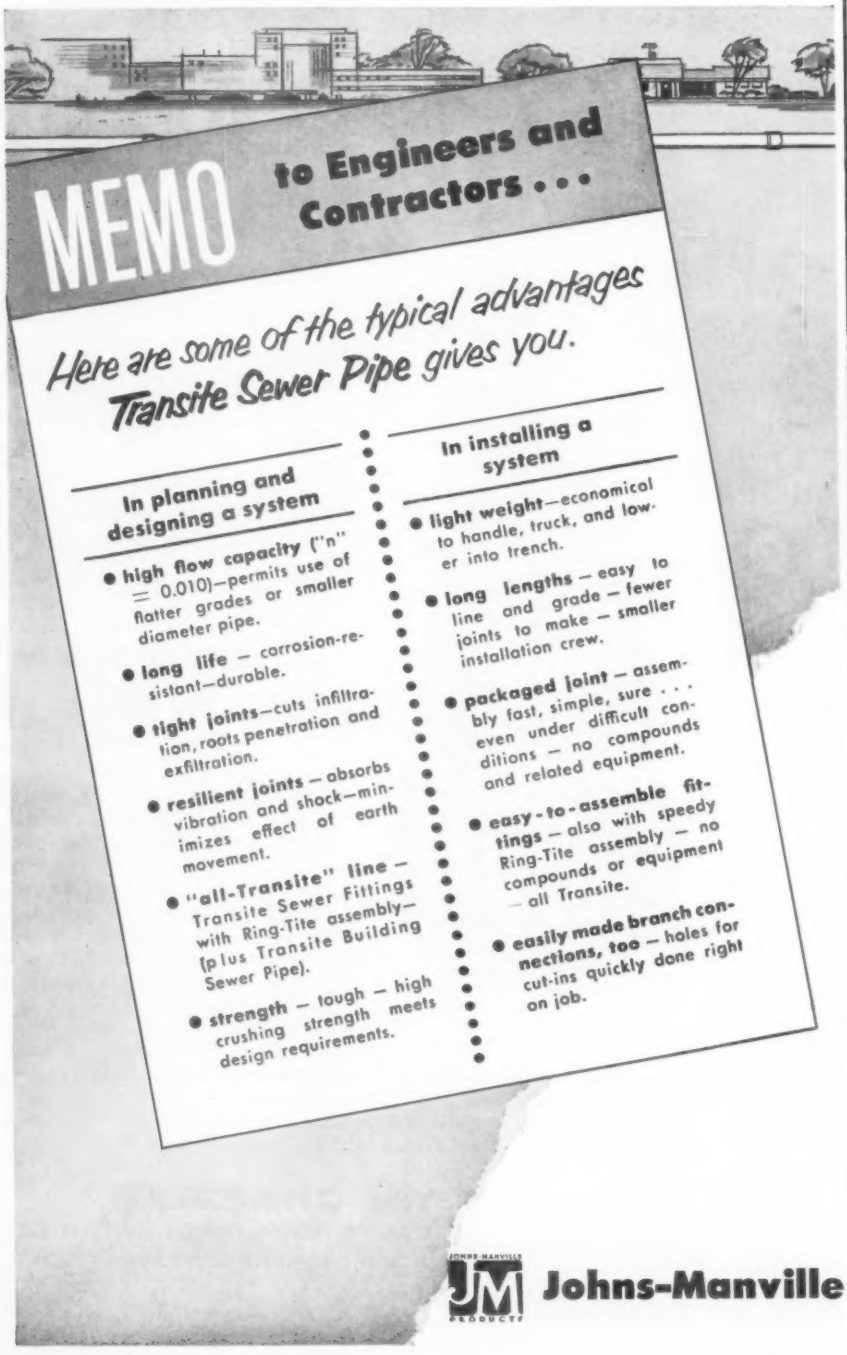
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Here are some of the typical advantages Transite Sewer Pipe gives you.
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● high flow capacity ("n" = 0.010)—permits use of flatter grades or smaller diameter pipe.
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● resilient joints — absorbs vibration and shock—minimizes effect of earth movement.
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● packaged joint — assembly fast, simple, sure . . . even under difficult conditions — no compounds and related equipment.
● easy-to-assemble fittings — also with speedy Ring-Tite assembly — no compounds or equipment — all Transite.
● easily made branch connections, too — holes for cut-ins quickly done right on job.
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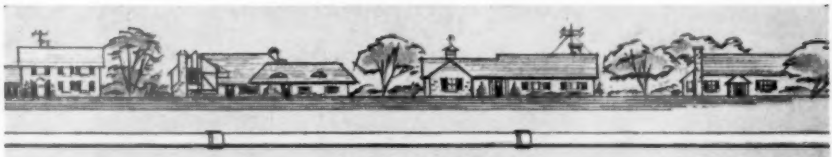

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Transite® for more economical, tighter sewerage systems . . .

WHETHER a new sewerage system is being planned or additions to an existing one are being made . . . engineer and contractor alike will find a combination of qualities in performance-proved Transite Sewer Pipe that will fit their individual needs. They will find this holds true whether the local conditions call for (a) tight joints to protect against root growth and infiltration of ground water or (b) the strength and flow characteristics that mean definite savings in the design stage, during trenching and installation, and in operation as well.

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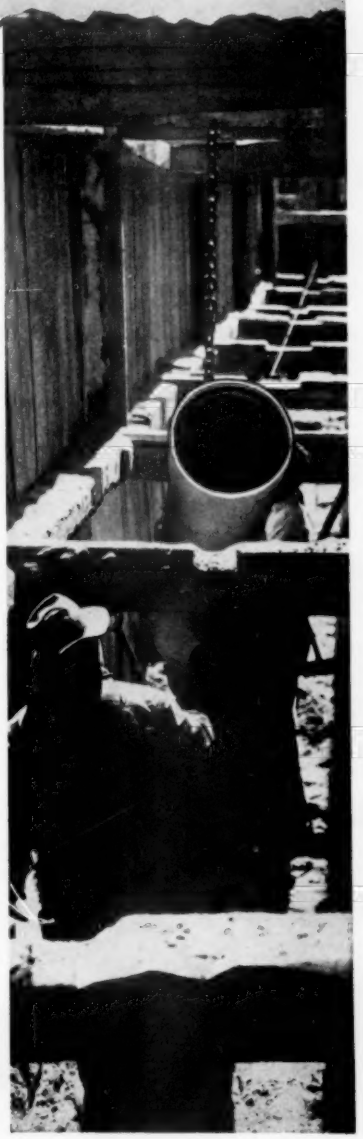

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with the RING-TITE® Coupling

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NO
LUBRICATION
WITH

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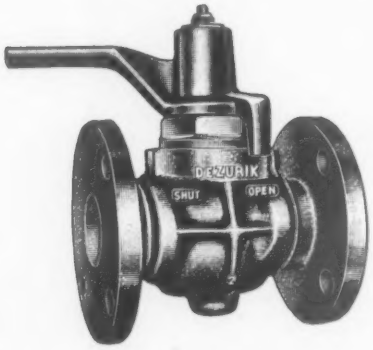

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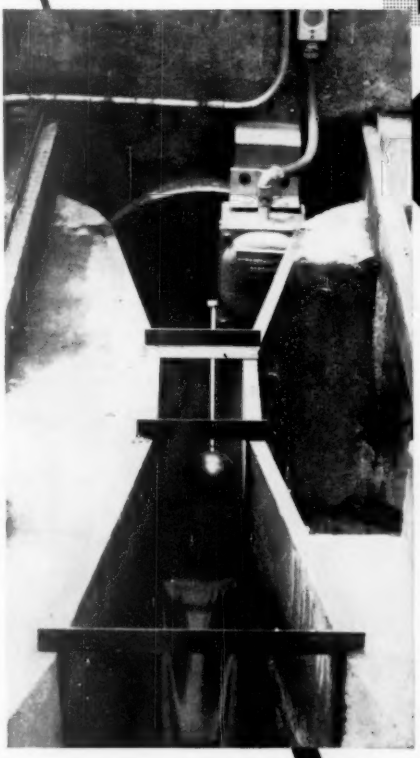

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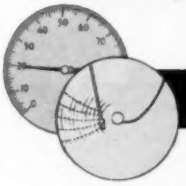

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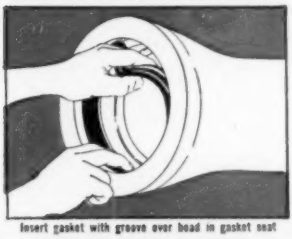
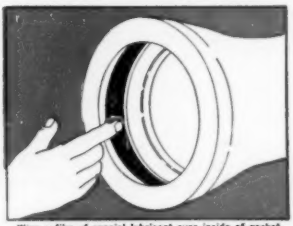
U. S. TYTON JOINT

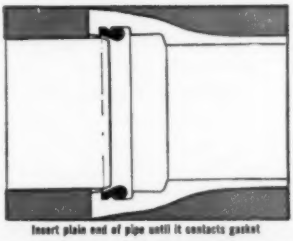
ONLY FOUR SIMPLE ACTIONS



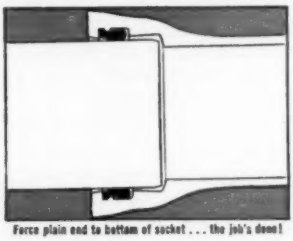
Insert gasket with groove over bead in gasket seat



Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!

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Pumping station of new $4,000,000 Linden—Roselle Sewage Treatment Plant. The entire plant is painted with Inertol coatings. Colorful Glamortex® quality alkyd, along with Ramuc® Utility Enamel and Ramuc Floor Enamel—both chlorinated natural rubber-base coatings in color—are but three of the Inertol paints chosen to attractively protect this plant.

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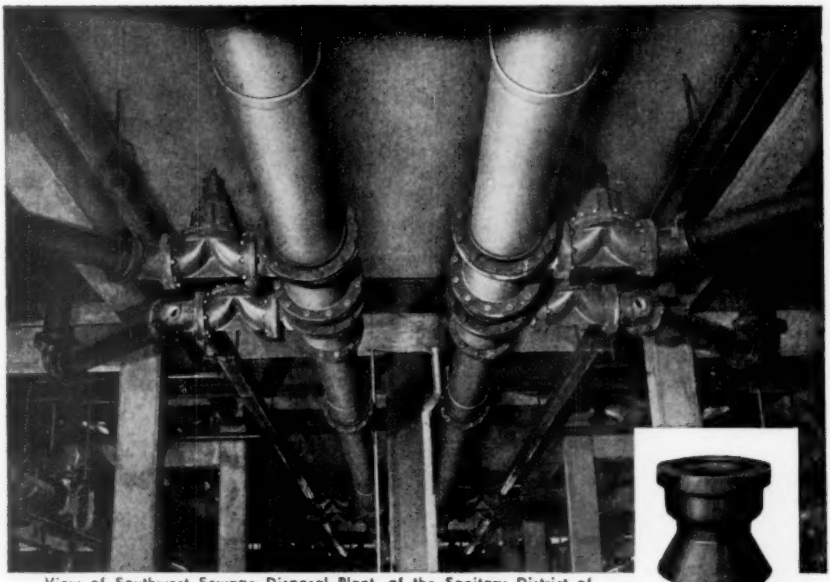
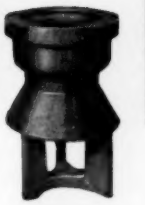


View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.



Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

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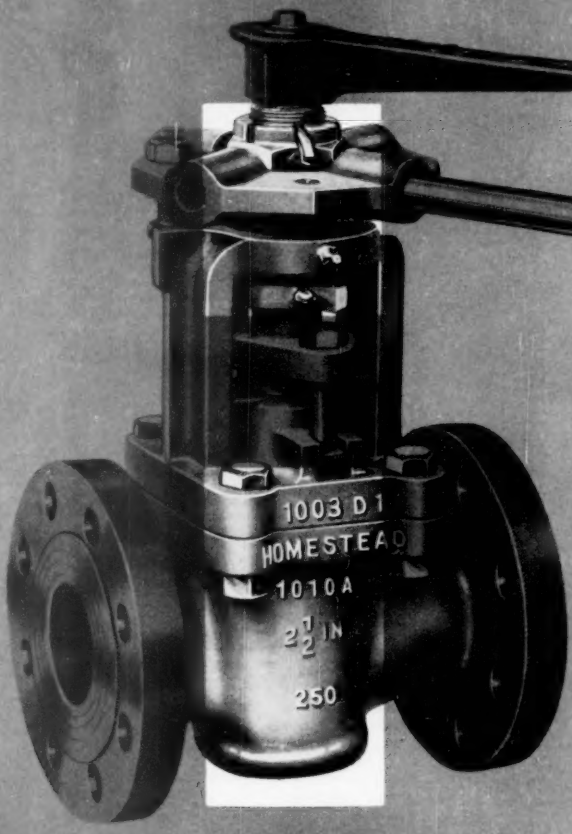
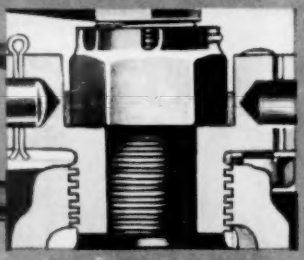
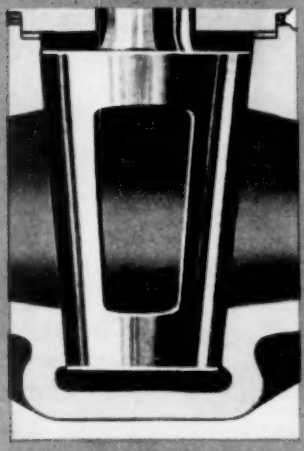




Built-in lever and screw affords instant operation



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Parkhill, Smith & Cooper, Lubbock, Texas • Consulting Engineers
Mr. M. Breneman — Plant Superintendent

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Full-sized plant tests conducted at SPARJER installations in recent years have demonstrated their superior design. In many cases SPARJERS are installed on existing headers which formerly supported diffusion tubes.

The complete SPARJER story is covered in Walker Process Bulletin Number 22S90. Here the theory and development is discussed in detail along with actual plant experience and data. Write for your copy today.

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3. *You save on maintenance costs*—Concrete Pressure Pipe has an experience record of almost complete freedom from corrosion and tuberculation. Elastic design virtually eliminates possibility of bursting—even under conditions of extreme surge and water hammer.

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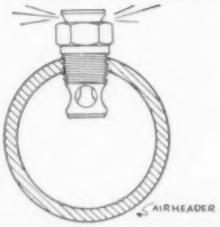
P.F.T. NEW DEVELOPMENTS IN SEWAGE TREATMENT



New, low cost P.F.T. valved-orifice achieves wide air dispersal and relatively small bubble size.

Low cost, trouble-free air for aeration tanks with new, non-clogging valved-orifice

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 29 | **December, 1957** | **Number 12**

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RALPH E. FUHRMAN, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
DR. F. W. MOHLMAN, *Advisory Editor* DONALD P. SCHIESSWOHL, *Assistant Editor*
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IT'S NEW / It's from DORR-OLIVER

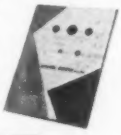
Aerial view of the Riverside, California Sewage Treatment Plant which recently incorporated the Dorr Densludge Digestion System to relieve badly overloaded digestion facilities. Consulting Engineer: Headman, Ferguson and Carollo, Phoenix, Arizona.

The Dorrco

DENSLUDGE DIGESTION SYSTEM

The new Dorrco Densludge Digestion System, already proven in full-scale treatment plants, is a new method of digesting sewage sludge that makes possible a reduction of up to 80% in digester capacity requirements compared with conventional systems. The basic operation of the Densludge Digestion System involves concentrating sludge ahead of digestion in a specially designed thickener, then digesting sludge in a Digester equipped with high-capacity draft tube mixers.

By removing the excess water in the raw sludge the Densludge Thickener reduces by one half, or more, the volume of raw sludge to the Digester. In the Digester, high capacity draft tube mixers insure full capacity utilization by maintaining homogeneous conditions throughout the tank. These reductions in sludge volume can now be directly translated into reductions in overall digester capacity requirements.



For more complete information on The Dorrco Densludge Digestion System, write for a copy of Bulletin No. 6262, Dorr-Oliver Incorporated, Barry Place, Stamford, Conn.

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Sewage Works

UNITED STATES SEWAGE TREATMENT PRACTICES DURING THE EARLY TWENTIETH CENTURY

By Ralph Porges

Senior Sanitary Engineer, Water Supply and Water Pollution Program, Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

It is appropriate occasionally to review the status of past sewage treatment practices in order to establish a firm basis for measurement of present and future progress. Sewage treatment in the United States is of relatively recent origin, having its start about 1880. There was a paucity of published statistics until about the middle of the 1930's when the magazine, *Engineering News-Record,* issued a comprehensive survey (1).

Hyde (2) encountered this lack of sewage treatment plant census data and states: "From many . . . sources, fragmentary and incomplete, a picture has been drawn . . . of the growth of sewerage and sewage treatment in the United States from 1860 to 1935." Even in recent times, statistics are not firm in many instances. However, an evaluation of all information on sources of pollution assembled by state health departments and water pollution control agencies, and by the United States Public Health Service, is underway currently and results will bring up to date the growth of sewerage and waste treatment.

It was with considerable interest, therefore, that an analysis was made of an early unpublished sewage treatment facility inventory (3) located in the files of the Robert A. Taft Sanitary Engineering Center of the Public Health Service. The report listed, by states, those communities with treatment facilities and specified the various treatment units. Virtually two inventories had been developed, one reporting those facilities installed prior to 1911 and the other, those installed after 1911. The group prior to 1911 constituted a 1910 inventory whereas the entire record formulated an inventory with an effective date established as about 1916.

The following pertinent explanatory note was carried in the report:

> "The list of treatment plants other than plain septic tank treatment alone includes at least 85 per cent of the plants now in operation in the United States, and serves at least 98 per cent of the population served by treatment plants other than septic tank.
>
> "It is not believed that the list insofar as plain septic tank treatment is concerned is as complete as in the case of other types of treatment. As a general rule, plants consisting of septic tanks only are operating very inefficiently."

It is unfortunate that these data were not published when originally assembled. The files indicate that press of other work occasioned by World War I, post war activities, and other assignments prevented completion of the report.

Data Limitations

With date of the 1910 compilation firmly established, the time of the overall inventory was determined by correlation with known references, since it carried no date of assembly. The com-

TABLE I.—Summary of 1910 Sewage Treatment Plant Inventory; Minor, Primary, and Intermediate Treatment

State	Total Installations		Minor Treatment						Primary Treatment				Intermediate Treatment			
			Screens		Disinfection		Septic Tank		Settling Tank		Imhoff Tank		Chemical Ppt.		Electrolytic Ppt.	
	No.	1910 Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
Alabama																
Arizona	3	30,764					2	17,571								
Arkansas	7	27,227					5	19,528								
California	87	327,503			(1)	(2,500)*	51	158,088	1	24,892					1	7,847
Colorado																
Connecticut	15	177,203														
Delaware																
District of Columbia																
Florida	7	24,234					5	13,033								
Georgia																
Idaho																
Illinois	36	190,450					24	147,375	3	16,690						
Indiana	6	64,710					1	8,716								
Iowa	34	175,408					9	34,567								
Kansas	41	131,674					24	86,633								
Kentucky	10	36,453					10	36,453								
Louisiana	1	11,449					1	11,449								
Maine																
Maryland	3	562,511			(2)	(4,026)*	1	943	1	3,083						
Massachusetts	32	449,007											(1)†	(145,986)†		
Michigan	13	81,093					7	33,813								
Minnesota	13	106,882					11	101,449								
Mississippi																
Missouri	2	5,014					1	5,014								
Montana	5	25,118														
Nebraska	1	9,338					1	9,338								
Nevada																
New Hampshire																
New Jersey	50	214,566			6	64,533‡	18	32,736								
New Mexico																

TABLE I.—Summary of 1910 Sewage Treatment Plant Inventory; Minor, Primary, and Intermediate Treatment (cont.)

State	Total Installations		Minor Treatment						Primary Treatment				Intermediate Treatment			
			Screens		Disinfection		Septic Tank		Settling Tank		Imhoff Tank		Chemical Ppt.		Electrolytic Ppt.	
	No.	1910 Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
New York	49	293,337	1	2,398	(1)	(1,293)*	8	36,293	3	9,836			6	29,840		
North Carolina	6	86,612					1	15,895								
North Dakota	7	23,345					7	23,345								
Ohio	40	442,540			(1)	(1,586)*			2	6,624						
Oklahoma	23	49,826					18	33,734								
Oregon	6	25,249					2	6,792								
Pennsylvania	16	203,931			(4)	(14,339)*	1	1,215								
Rhode Island	4	285,323					1	1,250					1	224,326		
South Carolina	2	12,020														
South Dakota	2	17,268					1	6,515								
Tennessee																
Texas	71	221,045			(6)	(8,510)*	31§	83,918§	2	3,447						
Utah	4	6,977					4	6,977								
Vermont																
Virginia	4	10,196														
Washington																
West Virginia																
Wisconsin	18	118,436					5	18,314	2	5,876						
Wyoming	1	8,408														
Total	619	4,455,117	1	2,398	6 (16)	64,533 (44,705)*	250	950,954	14	70,448			7	254,166	1	7,847

* In conjunction with other treatment. Parentheses indicate numbers included elsewhere.
† Chemical precipitation and intermittent sand filters.
‡ In addition, 1 plant serving 12,451 with other treatment.
§ Four plants, not specified.

TABLE II.—Summary of 1910 Sewage Treatment Plant Inventory; Secondary Treatment

State	Secondary Treatment										Land Application					
	Contact Beds		Trickling Filters		Intermittent Sand Filters		Unspecified Filters		Activated Sludge		Broad Irrigation		Sewage Farm		Sub-surface Irrigation	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
Alabama																
Arizona											1	13,193				
Arkansas							2	7,699								
California	4	32,567			3	8,299							26	94,840	1	970
Colorado																
Connecticut			1	28,646	14	148,557										
Delaware																
District of Columbia																
Florida	2[a]	11,201[a]														
Georgia																
Idaho																
Illinois	2	3,727	2	7,426	4	10,901	1	4,331								
Indiana	(2)[b]	(11,448)[b]			4	39,192	1	16,802								
Iowa					25	140,841										
Kansas	15	42,067					1	—							1	2,974
Kentucky																
Louisiana																
Maine																
Maryland			1	558,485												
Massachusetts			(1)[c]	(56,878)[c]	31[c]	445,932[c]					1	3,075				
Michigan	1	6,230			5	41,050										
Minnesota			1	2,475	1	2,958										
Mississippi																
Missouri	1	—														
Montana	2	3,046			1	4,697					2	17,375				
Nebraska																
Nevada																
New Hampshire																
New Jersey	5	55,719			20	60,781					1(2)[d]	797				
New Mexico																

TABLE II.—Summary of 1910 Sewage Treatment Plant Inventory; Secondary Treatment (cont.)

State	Secondary Treatment										Land Application					
	Contact Beds		Trickling Filters		Intermittent Sand Filters		Unspecified Filters		Activated Sludge		Broad Irrigation		Sewage Farm		Sub-surface Irrigation	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
New York	15	117,184	6	50,272	9	46,218	1	1,296								
North Carolina	5	70,717														
North Dakota																
Ohio	13	98,031	2	184,245	22	146,455	1	7,185								
Oklahoma	1	3,165	4	12,927												
Oregon							2	11,598			2	6,859				
Pennsylvania	9	33,505	4	117,084	1	52,127					1	—				
Rhode Island			1	38,125	1	21,622										
South Carolina	1	8,109			1	3,911										
South Dakota			1	10,753												
Tennessee																
Texas	22	76,255	2	2,638	3	12,433	1	4,732					1	1,750	9	35,872
Utah																
Vermont																
Virginia	2	6,739									2	3,457				
Washington																
West Virginia																
Wisconsin	2	44,328	1	6,645	1	3,346	7	39,927								
Wyoming					1	8,408										
Total	102	612,590	26	1,019,721	147	1,197,728	17	93,570			10	44,756	27	96,590	11	39,816

[a] Coke beds.
[b] Contact beds and intermittent sand filter.
[c] Trickling filter and intermittent sand filter at one community.
[d] Two broad irrigation plants included under sand filters.

TABLE III.—Summary of 1916 Sewage Treatment Plant Inventory; Minor, Primary, and Intermediate Treatment

State	Total Installations		Minor Treatment						Primary Treatment				Intermediate Treatment			
			Screens		Disinfection		Septic Tank		Settling Tank		Imhoff Tank		Chemical Ppt.		Electrolytic Ppt.	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
Alabama																
Arizona	4	33,157					2	17,571			1	2,393				
Arkansas	7	27,227					5	19,528								
California	98	354,775	2	13,448	(1)	(2,500)*	52	158,088	1	24,892	2	3,461			1	7,847
Colorado																
Connecticut	17	190,147			(1)	(11,272)*					1	11,272				
Delaware																
District of Columbia																
Florida	21	87,849	2	4,458			5	13,033			12	59,157				
Georgia	1	154,839														
Idaho																
Illinois	40	201,014					24	147,375	3	16,690						
Indiana	6	64,710					1	8,716								
Iowa	42	208,939					10	34,943								
Kansas	41	152,345					26	98,662			2	4,675				
Kentucky	13	78,708					10	36,453			1	7,156				
Louisiana	2	16,072					1	11,449								
Maine																
Maryland	4	562,511			(2)	(2,046)*	1	943	1	3,083						
Massachusetts	33	449,007											(1)†	(145,986)†		
Michigan	14	82,783					7	33,813	1	1,690						
Minnesota	13	106,882					11	101,449								
Mississippi																
Missouri	4	5,477					2	5,014								
Montana	5	25,118														
Nebraska	1	9,338					1	9,338								
Nevada																
New Hampshire																
New Jersey	198	291,853	1	898	2‡	17,763‡	18	32,736	29	96,824						
New Mexico																

TABLE III.—Summary of 1916 Sewage Treatment Plant Inventory; Minor, Primary, and Intermediate Treatment (cont.)

State	Total Installations		Minor Treatment						Primary Treatment				Intermediate Treatment			
			Screens		Disinfection		Septic Tank		Settling Tank		Imhoff Tank		Chemical Ppt.		Electrolytic Ppt.	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
New York	56	702,579	1	2,398	(1)	(1,293)*	8	36,293	3	9,836	3	321,705	6	29,840		
North Carolina	8	98,540			1	8,051	1	15,895			1	3,877				
North Dakota	7	23,345					7	23,345								
Ohio	50	603,555			(2)	(10,128)*			2	6,624	2	17,629			1	3,537
Oklahoma	41	104,145					18	33,734			9	19,144			1	5,330
Oregon	6	25,249					2	6,792								
Pennsylvania	27	268,277			(5)	(26,530)*	1	1,215			1	12,191				
Rhode Island	5	308,077					1	1,250					1	224,326		
South Carolina	4	24,264														
South Dakota	2	17,268					1	6,515								
Tennessee	1	4,007														
Texas	138	709,827			(25)	(106,447)*	31§	83,918§	2	3,447	8	169,415				
Utah	4	6,977					4	6,977								
Vermont																
Virginia	6	16,310									1	4,897				
Washington																
West Virginia																
Wisconsin	20	121,798					5	18,314	2	5,876	2	3,362				
Wyoming	1	8,408														
Total	846	6,145,327	6	21,202	3	25,814	255	963,359	44	168,962	46	640,334	7	254,166	3	16,714
					(52)	(255,699)*										

* In conjunction with other treatment. Parentheses indicate numbers included elsewhere.
† Chemical precipitation and intermittent sand filters.
‡ Fourteen plants serving 95,483 with other treatment.
§ Four plants, not specified.

TABLE IV.—Summary of 1916 Sewage Treatment Plant Inventory; Secondary Treatment

State	Secondary Treatment										Land Application					
	Contact Beds		Trickling Filters		Intermittent Sand Filters		Unspecified Filters		Activated Sludge		Broad Irrigation		Sewage Farm		Sub-surface Irrigation	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
Alabama																
Arizona											1	13,193				
Arkansas							2	7,699								
California	4	32,567	2	—	3	8,299							30	105,203	1	979
Colorado																
Connecticut			1	28,646	15	150,229										
Delaware																
District of Columbia																
Florida	2[a]	11,201[a]														
Georgia			1	154,839												
Idaho																
Illinois	2	3,727	4	12,297	6	16,594	1	4,331								
Indiana	(2)[b]	(11,448)[b]			4	39,192	1	16,802								
Iowa			1	11,230	29	152,827	2	9,939								
Kansas	17	46,034					1	—							1	2,974
Kentucky			2	35,099												
Louisiana			1	4,623												
Maine																
Maryland			1	558,485	1	—										
Massachusetts			1 (1)[c]	(56,878)[c]	31[c]	445,932[c]					1	3,075				
Michigan	1	6,230			5	41,050										
Minnesota			1	2,475	1	2,958										
Missippi																
Missouri	1	—	1	463												
Montana	2	3,046			1	4,697					2	17,375				
Nebraska																
Nevada																
New Hampshire																
New Jersey	6	32,296	7	34,007	29	64,213					4 (2)[d]	12,528			2	588
New Mexico																

TABLE IV.—Summary of 1916 Sewage Treatment Plant Inventory; Secondary Treatment (cont.)

State	Secondary Treatment										Land Application					
	Contact Beds		Trickling Filters		Intermittent Sand Filters		Unspecified Filters		Activated Sludge		Broad Irrigation		Sewage Farm		Sub-surface Irrigation	
	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population	No.	Population
New York	15	117,184	9	136,241	9	46,218	1	1,296			1	1,568				
North Carolina	5	70,717														
North Dakota																
Ohio	14	148,248	3	253,312	27	167,020	1	7,185								
Oklahoma	4	7,524	7	35,251					1	685	1	2,477				
Oregon							2	11,598			2	6,859				
Pennsylvania	9	33,505	12	168,431	3	52,885					1	—				
Rhode Island			2	60,879	1	21,622										
South Carolina	1	8,109	2	12,244	1	3,911										
South Dakota			1	10,753												
Tennessee			1	4,007												
Texas	34	107,569	28	131,072	4	12,433	9	26,218	7	123,046			2	11,707	13	41,002
Utah																
Vermont																
Virginia	2	6,739	1	1,217							2	3,457				
Washington																
West Virginia																
Wisconsin	2	44,328	1	6,645	1	3,346	7	39,927	(1)[e]	—						
Wyoming					1	8,408										
Total	121	679,024	90	1,662,216	172	1,241,834	27	124,995	8	123,731	15	60,532	32	116,910	17	45,534

[a] Coke beds.
[b] Contact beds and intermittent filters.
[c] One trickling filter and intermittent sand filters.
[d] Two broad irrigation plants included under sand filters.
[e] Experimental plant for 3 m.g.d. at Milwaukee.

TABLE V.—Summary of Sewage Treatment Data, 1910 and 1916

Item	1910		1916	
	Plants (No.)	Population (1910 Census)	Plants (No.)	Population (1910 Census)
Communities	619	4,455,117	846	6,145,327
Minor treatment:				
Screens	1	2,398	6	21,202
Disinfection (alone)	6	64,533	3	25,814
Septic tanks	250	950,954	255	963,359
Total	257	1,017,885	264	1,010,375
Primary treatment:				
Settling tanks	14	70,448	44	168,962
Imhoff tanks	—	—	46	640,334
Total	14	70,448	90	809,296
Intermediate treatment:				
Chemical	7	254,166	7	254,166
Electrolytic	1	7,847	3	16,714
Total	8	262,013	10	270,880
Secondary treatment:				
Contact beds	102	612,590	121	679,024
Trickling filters	26	1,019,721	90	1,662,216
Intermittent sand filters	147	1,197,728	172	1,241,834
Unspecified filters	17	93,570	27	124,995
Activated sludge	—	—	8	123,731
Total	292	2,923,609	418	3,831,800
Land Application:				
Broad irrigation	10	44,756	15	60,532
Sewage farms	27	96,590	32	116,910
Subsurface irrigation	11	39,816	17	45,534
Total	48	181,162	64	222,976

munity population referred to throughout the report was that of the 1910 United States Census. A brief review of correspondence during the latter half of the second decade revealed communications with various state engineers regarding collection of sewage data. In fact, more than 500 cities were surveyed by Public Health Service personnel prior to 1918 as part of sanitary investigations of communities made in connection with preliminary extra-cantonment zone sanitation. Indications are that information on most of the states must be dated 1916 although that from Texas may be 1918. Accordingly, the date of the over-all inventory was judged to be about 1916.

As may be noted from the quotes of the original report, the data are claimed to be 98 per cent complete as to population served by sewage treatment plants other than septic tanks. At least 85 per cent of the plants are included. Septic tank data are probably less complete but the plants omitted were the smaller installations. The report indicated that data on only six states (Conn., Fla., Mass., N. J., Okla., and Texas) were essentially complete. Even considering the incompleteness of the data, they probably provide the most accurate available information for the early period of rapid growth of sewage treatment in the United States.

Presentation of Data

Summaries of the compilations by states are presented in Tables I and II (1910 data) and Tables III and IV

(1916 data). The information was tabulated as follows:

1. Minor treatment—screens, disinfection and septic tanks.
2. Primary treatment—settling tanks and Imhoff tanks.
3. Intermediate treatment—chemical precipitation and electrolytic precipitation.
4. Secondary treatment — contact beds, trickling filters, intermittent sand filters, unspecified filters and activated sludge.
5. Land application — broad irrigation, sewage farms and subsurface irrigation.

Each facility was listed in accordance with the last major treatment function. For example, a treatment plant having a septic tank followed by a contact bed was tabulated only in the contact bed listing. Likewise a trickling followed by intermittent sand filtration was totalled only in the latter listing. Generally speaking, virtually all sewage treatment plants installed prior to 1911 utilized septic tanks regardless of the ultimate disposal method employed. After 1911, Imhoff tanks were generally used in new installations. The population listings are 1910 United States Census figures.

Summary data for both 1910 and 1916 are presented in Table V. In 1910, sewage treatment facilities served 619 communities with a total popula-

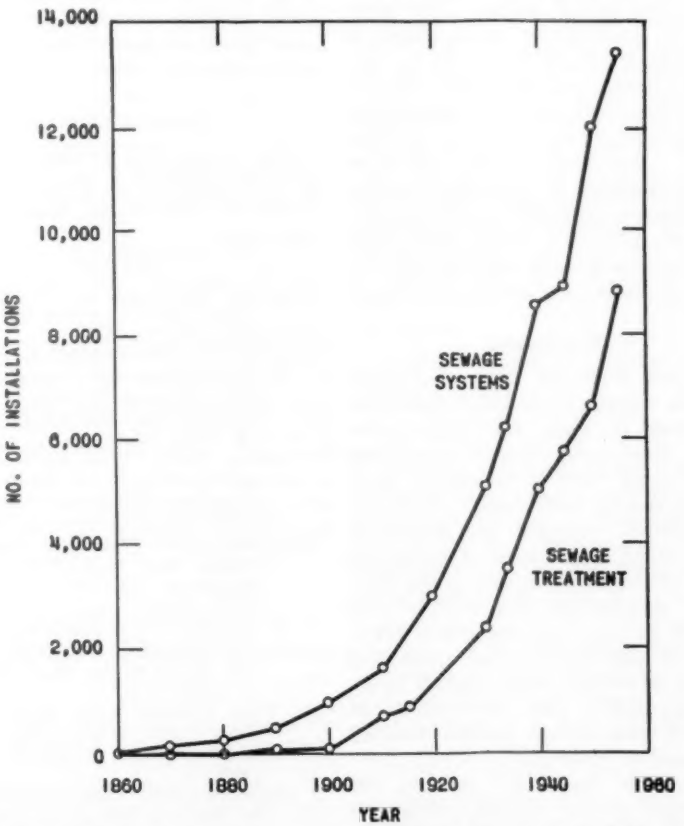

FIGURE 1.—Growth of sewage systems and sewage treatment in the United States, 1860 to 1955.

tion of 4,455,117. Minor treatment, principally septic tanks, accounted for 257 communities. There were 14 settling tanks and 8 intermediate treatment faciilties. Secondary treatment, mainly intermittent sand filtration and contact beds, was practiced by 292 communities. Land application was reported in 48 instances, well represented by the three indicated methods—broad irrigation, sewage farms, and subsurface irrigation.

By 1916, the number of communities served rose to 846 with a population in excess of six million people. Minor treatment facilities increased slightly. Primary treatment increased more than six-fold, reaching 90 installations about equally divided between settling tanks and Imhoff tanks. Two intermediate installations were added to the eight of the 1910 inventory. Secondary treatment increased substantially from 292 to 418 installations. The largest increase was in trickling filters. Activated sludge treatment plants appeared at this time, serving eight communities with a total population of 123,731. Land application units increased to 64 with all land disposal methods represented in the increase.

Discussion

Several pertinent facts of interest may be drawn from the information contained in these historic compilations. These early observers noted that installations limited to septic tanks were operating inefficiently. This lack of efficiency presaged the demise of septic tanks as a means of municipal waste treatment. Increase in the number of installations from 1910 to 1916 of both primary and secondary treatment is significant. The increasing number of settling tanks, Imhoff tanks, trickling filters, and development of the activated sludge process foretold the trend of progress.

For 1910, Hyde (2) records 300 treatment plants serving 4,000,000 people. The Tarbett (3) tabulation shows 619 plants serving a population of 4,455,000. The latter listing is probably more complete. For 1920, Hyde (2) lists 1,000 plants, a number which appears low when compared with the 1916 data. Figure 1 depicts the growth of sewage systems and treatment units in the United States from 1860 to 1955 (1)(2)(4)(5)(6)(7). In this period, the number of sewage systems increased from 10 to about 13,500; whereas the number of sewage treatment plants increased from 0 to 8,400.

Summary

A summary of two unpublished compilations of municipal sewage treatment plants dated 1910 and 1916 has been presented. These data supplement existing records of sewage treatment progress during the early years of the twentieth century.

Acknowledgment

Full recognition is made of the efforts of the late R. E. Tarbett, Sanitary Engineer, USPHS, in compilation of these data.

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SLUDGE CONDITIONING AND FILTRATION AT CINCINNATI'S LITTLE MIAMI SEWAGE WORKS *

By Dean Taylor †

Senior Sanitary Engineer, Sewage Disposal Section, Department of Public Works, Cincinnati, Ohio

The Little Miami sewage treatment works of Cincinnati, Ohio, is a primary treatment plant with provision for flocculation with or without chemical aid (alum). Provision is also made for pre- and post-chlorination. Neither chemical flocculation nor chlorination is presently practiced.

Plant capacity was designed for an average flow of 18 m.g.d. in 1951 and 28.8 m.g.d. in 1980. Treatment was based on a sewage quality of 250 p.p.m. suspended solids and 270 p.p.m. B.O.D. Present average flow is 13.5 m.g.d., with an average raw sewage quality of 270 p.p.m. suspended solids and 130 p.p.m. B.O.D.

Primary settling tank sludge is drawn once a day from each of three operating tanks (one tank per shift), pumped through heat exchangers where it is heated to 90° to 95° F., and digested in two stages. Sludge is drawn each shift from each tank during hot weather. No heat is applied to the secondary stage. Digested sludge from the secondary digesters is elutriated, chemically conditioned with ferric chloride, vacuum filtered, and burned to ash.

Process Principles

Mechanical filtration of sewage sludge saves much time and space. Rotary vacuum filters provide continuous operation with minimum labor cost. Filter installations can be sized from data showing quantities of sludge solids to be filtered, sludge characteristics, filtration rates, cake moistures, and filter operation variables. Unfortunately, the only factors usually known for design are the methods of sludge treatment and the quantities of sludge to be filtered. It is true that some of the other factors could be estimated from experimental work, but this is difficult and no such case is known. The next best procedure is to use average data from plants using similar sewage treatment methods. Schepman (1) has discussed this subject in a recent article.

Factors affecting sludge filtration may be placed in three general classes, as follows:

1. Physical features of the installation.
2. Sludge characteristics.
3. Filter operations.

Sewage treatment plant operators usually have little choice in dealing with filter layouts, because they enter the picture after construction has been completed. Sludge characteristics vary considerably with time and place, and require careful study for effective filtration. Filter operators should understand the basic principles of filtration and then apply them to the sludge and equipment at their disposal.

Physical Features

Filter manufacturers and consulting engineers are responsible for most filter

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† Presently, Superintendent of Sewage Disposal, Louisville-Jefferson County Metropolitan Sewer District, Louisville, Ky.

layouts. Recent activity by the former has stimulated improvements in design. Genter (2)(3)(4) has discussed construction and installation factors affecting sludge filtration. He points out the importance of such mechanical features as proper vacuum pump sizing, not oversizing conditioning mixing equipment, not using inverted feed piping, proper distribution of the inflowing sludge through the filter bath, proper control of agitators, drum submergence, and scraper levels.

Sludge Characteristics

Sludge characteristics are determined by the sludge source and the methods of treatment. Sludges from domestic sewage are relatively similar, but industrial waste sludges may vary considerably. Sludge treatment methods change sludge characteristics; therefore, it is important to properly evaluate variables before attempting to integrate them into a practical filter operation. Sludge characteristics include such factors as particle size, solids concentration, density of solids, solids structure, grease content, and compressibility. Their net effect may be summarized by a term called "filtration resistance."

Filter Operations

Dry solids rate and cake moisture are the primary considerations in filter operation. Early investigators (5)(6)(7)(8) applied the theoretical approach to filtration of industrial sludges. However, their results were not based on data for a filtration process which included the drying cycle used in the rotary vacuum filtration of sewage sludges. Halff (9) developed a theoretical method which confirmed the conclusion of others that filtration follows a parabolic relationship. His approach is difficult, however, and other workers have not used it.

Most workers have used the Buchner funnel test to measure the filterability of sewage sludges. This test is of value in indicating trends in filtration, but it is not applicable to full-scale rotary filtration. It only compares treatments by a worker on his own sludge. Coackley and Jones (10) have developed a useful parameter which they call "specific resistance." It has a sound theoretical basis and permits comparison of different types of sludges. Jones (11) has worked further with the use of specific resistance and claims to be able to predict rotary vacuum filter performance from a few simple laboratory experiments. Because it is based on the use of a Buchner funnel, this does not appear possible.

Schepman and Cornell (12) published data showing good correlation between pilot-plant operation and a laboratory technique based on a leaf filter. The value of the leaf test in determining sludge filter station design and the optimum conditions for an operating plant was also demonstrated. They concluded that filter rates increase (a) logarithmically with increasing drum speed, (b) logarithmically with increasing vacuum, (c) linearly with increasing solids concentration, and (d) with increasing flocculant dosage up to a certain point after which increased chemical additions gave little or no increase in rate. They also concluded that cake moisture is a function of drying vacuum, chemical dosage, and drying or cycle time, with the latter being the most significant.

Sludge conditioning is necessary before vacuum filtration. The first records of such work in this country were made at Milwaukee and Chicago in the early 1920's (13)(14)(15)(16). Workers suggested use of such agents as heat, acid, alum, ferric chloride, ferric sulfate, and lime, separately or in combination.

Genter has written the most comprehensive articles on sludge conditioning for filtration (3)(4)(17)(18). He concluded that digested sludges required more conditioning chemicals than fresh sludges largely because of

the soluble decomposition products (largely ammonium bicarbonate) generated during anaerobic digestion. He stated that coagulant demand was the sum of two factors—liquid demand and solids demand. Equations were developed to determine these demands, but he conditioned their value by saying that they apply to carefully dosed sludge, free of chemical reducing agents, oil emulsions, and large fractions of fines. He finally patented the elutriation process for washing out the alkalinity of the biochemically fouled sludge by dilution, sedimentation, and decantation in water of lower alkalinity.

Equipment Specifications

Filtration

Filter specifications call for three 6-ft. by 8-ft. drum filters capable of handling 225 tons of 8 per cent sludge daily. Based on five-day, 24-hr. operation this would require a filter rate of 3⅓ lb. per square foot per hour. On a five-day basis two filters would be capable of handling the anticipated sludge load of 21,700 lb. of dry solids in 1953. Four filters were finally installed. In 1980, 3.67 (or all four) filters would be required to filter the anticipated daily sludge loading of 44,100 lb. when chemical precipitation is used. Otherwise, the filter rate would have to be raised to 4.1 lb. per square foot per hour to permit the operation of three filters.

Sludge Conditioning

Conditioning of digested sludge is based on elutriation and coagulation with ferric chloride. It was necessary to obtain a license to use the patented process of sludge elutriation.

Two mixing and two settling tanks are provided for elutriation of digested sludge and supernatant. They are arranged for either counterflow or single-flow continuous operation. Three bucket elevators move sludge to the elutriation tanks from storage wells and from the elutriation tanks to the mixer ahead of the filter. Flight collectors drag settled sludge solids back to sumps at the inlet ends of the tanks.

The mixing tanks are 8 ft. by 7 ft. by 5.25 ft. deep and the settling tanks 44 ft. by 12 ft. by 12 ft. deep. Liquid depth in the mixing tanks is 2.5 ft. Using a 3:1 wash-water rate, theoretical displacement times are 3 to 19 min. in the mixing tanks and 2.4 to 14 hr. in the settling tanks. Possible area flows in the settling tanks are 151 to 909 gal. per square foot per day.

Elutriated sludge is mixed with dilute ferric chloride (about 21 per cent) in a 150-gal tank equipped with a two-paddle horizontal agitator. Speed regulation of the agitator varies from 4 to 10 r.p.m. The elutriated sludge elevator is interlocked with the ferric chloride feeder, which is of the volumetric type and capable of delivering from 0 to 100 g.p.h. Each filter tank is fed by a separate 6-in. pipe from the the mixer. These pipes enter the tanks on the ends nearest the mixer, which sits between the two pairs of filters. Six-inch overflow lines in the tanks regulate sludge depth. Swing-type agitators in the tanks prevent deposition of solids. A single conveyor belt between the two pairs of filters in tandem carries sludge from the filters to the incinerators.

Two vacuum pumps, two compressors, two filtrate pumps, and supplemental equipment are provided for three filters. An additional unit of one vacuum pump, one compressor, and one filtrate pump is also provided. Each unit of vacuum pumps, compressors, and filtrate pumps is capable of serving one or both of two filters. Each vacuum pump has a displacement of not less than 600 c.f.m. and is capable of producing not less than 26-in. of vacuum (mercury).

Incineration

Two five-hearth furnaces with rotating rabble arms are provided for dry-

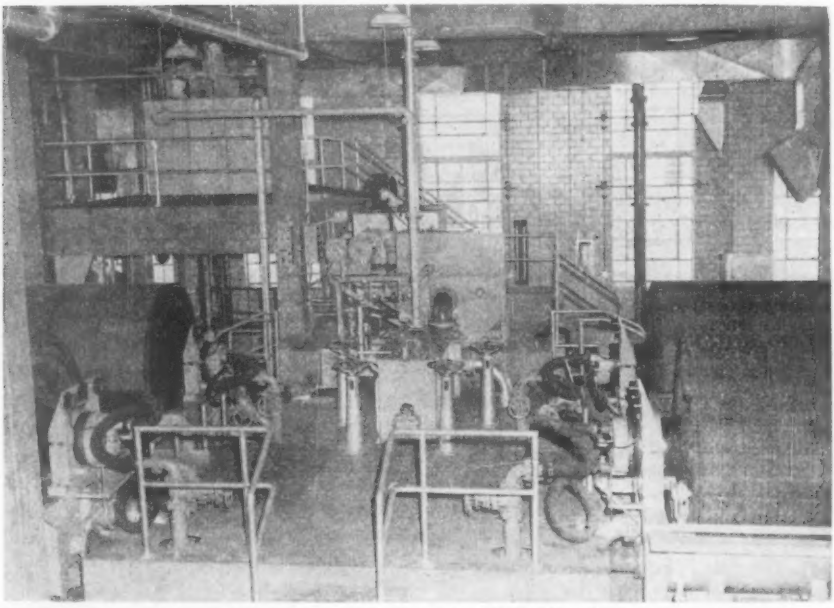

FIGURE 1.—Vacuum filter room at Cincinnati's Little Miami sewage treatment plant.

ing the sludge or burning it to ash. Each furnace is capable of dewatering and incinerating 45 tons of filter cake per 24 hr. This rating is based on a filter cake with a moisture content of 70 per cent, total solids content of 30 per cent, combustible solids content of 15 per cent, ash content of 15 per cent, and a heat value of 10,000 B.t.u. per pound of combustible solids.

Filter and Sludge Conditioning Operations

Figure 1 shows the filter layout. Filters have been operated on a five-day week for the most part. The elutriation tanks sit full over the week-end; digested sludge is fed into the tanks just after midnight on Monday morning. Filtration is started on Monday morning between 4 and 8 A.M. and continues until Friday night. Consequently, the heaviest sludge (up to 13 per cent dry solids) has been available for filtration on Monday. Sludge concentration drops off to 5 to 7 per cent by Friday, depending on digested sludge concentration and elutriation operation.

Both counterflow and single-stage elutriation have been practiced. Wash-water rates of 3:1 or 4:1 have been used with the former and 6:1 with the latter. When single-stage elutriation is used, the sludge-water mixture is passed through one settling tank and then only the washed sludge is passed through the second tank.

To date, daily filtration rates have ranged from 0.8 to 3.0 lb. per square foot per hour, with an average of only 1.5 lb. All four filters would have to operate 24 hr. for five days to handle the daily sludge load from the digesters of 16,000 lb. dry solids. The filters have been operated seven days a week during some periods. Also, digested sludge has been dumped into the Ohio River during flood stages. Thus, it is possible to handle the filter load. However, it will be necessary to raise filter rates to meet increasing future solids loads.

Plant Studies

Opportunity to study operational variables of full-scale filtration has been limited. Operational records are difficult to interpret because there are so many variables. Graphical study of such factors as drum speed, vacuum, sludge concentration, ferric chloride dosage, and filter yield shows certain relations, but statistical analysis shows poor correlation. Parameters are available for most filtration variables with the exception of blinding.

Filter yield is considered more important than cake moisture because filter capacity is very limited and incinerator capacity is high.

Filter Operations

Drum speed, agitator operation, and drum spraying are the only operational variables. Experience shows that the agitators should only be used when sludge solids build up in the filter tank sections farthest from the inlet. This is usually every 2 to 3 hr., with operation for only about 1 min. Drums are only sprayed when blinding occurs. Blinding is so variable that spraying is left to the discretion of the operators. Spraying may be required every few hours or only every few days.

Limited data have been obtained on the effects of drum speed and sludge solids concentration on filter yields. Using the conventional drum speed unit, cycle time in minutes, Figure 2 shows that yield is directly proportional to both variables. The relation between drum speed and yield is logarithmic, whereas that between sludge

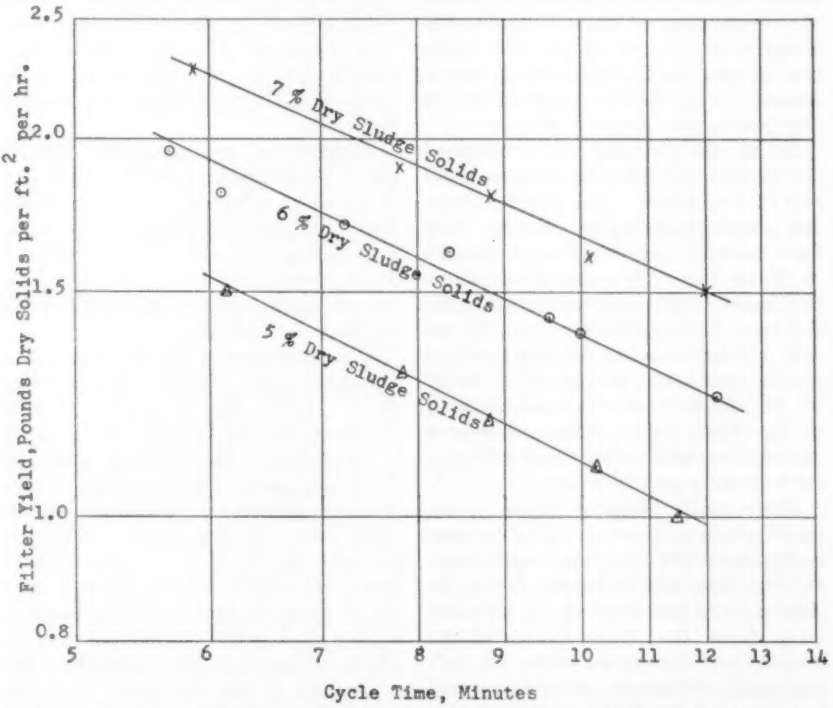

FIGURE 2.—Effect of drum speed and sludge solids concentration on filter yield; elutriated, digested sludge, Little Miami sewage plant. Ferric chloride dosage, 5 per cent; vacuum, 25 in. Hg.

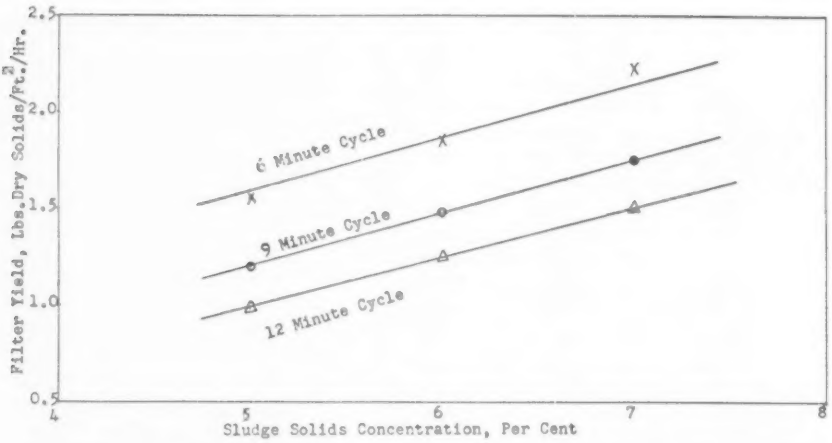

FIGURE 3.—Effect of sludge solids concentration and drum speed on filter yield; elutriated, digested sludge, Little Miami plant. Ferric chloride dosage, 5 per cent; vacuum, 25 in. Hg.

solids and yield is straightline. Using the same data, Figure 3 shows the straightline plot of solids concentration versus yield with varying drum speeds. This confirms the work of Schepman and Cornell (12).

No specific data have been obtained on the effect of filter vacuum on yield and cake moisture. The valves of both the pickup and drying vacuum lines have usually been set to produce 25 to 27 in. Hg. This usually produces maximum yield and minimum cake moisture, which averages about 65 per cent. Sometimes the operators reduce drying vacuum to as low as 15 to 20 in. Hg to prevent the cake sticking to the filter cloth. This produces a wetter cake, which they think will prevent sticking and blinding.

Filter cloth blinding is an operational problem that can only be partially controlled by proper operations. If the cake will separate from the cloth at the air blow-off, it will fall away from the drum ahead of the scraper and be guided onto the belt conveyor. Otherwise, the scraper will have to peel it off the cloth and this becomes practically impossible if the cake is thin and sticks to the cloth. This is particularly true when wooden drum filters are used, especially when they warp out of round; the scraper can be bent to fit only parts of the drum and there is danger of gouging the cloth.

Enough is not presently known about the characteristics of sludge constituents to relate them to filter blinding. The effects of sludge conditioning on blinding are not fully understood. It is known, however, that too little or too much ferric chloride will cause sticking to the cloth.

Cake thickness is the one factor having the greatest effect on filter blinding in the Little Miami plant. If cake thickness can be brought up to ¼ in. or more, the cake quickly separates from the cloth. Sludge solids concentration controls cake thickness for the most part, because when solids are brought up to about 8 per cent or more, cake thickness immediately goes up to ¼ in. or more. Ferric chloride dosage and drum speed can then be easily adjusted to give optimum yield with little if any blinding. It is not unusual to produce ½-in. cakes on Monday mornings when the filters start up with 10 to 12 per cent sludge.

Such operations would double or triple present yields.

Selection of filter media has been based on limited information. Three synthetic materials other than flannel have been tried. Saran, Dynel, or polyethylene gave no better results than flannel and cost about 50 per cent more. Average cloth life has been 1,200 hr. There is need for further filter cloth study, particularly with reference to material texture and porosity.

Elutriation

Elutriation has been a bottleneck in the sludge disposal program because production by this process has been below plant loading requirements. Recirculation of sludge solids to the plant influent may be as high as 25 per cent of feed to elutriation when operations are speeded up to plant loading requirements. Moreover, solids concentrations of elutriated sludge fall off to 5 to 7 per cent, causing blinding on the filters.

Eight to 12 per cent solids can be obtained from the sludge hoppers for filtration on Monday morning after the elutriation tanks have stood quiescent over the weekend. Concentration falls off quickly, however, to 5 to 7 per cent by Tuesday, if feed rates are maintained. Loss of solids over the effluent weirs can be reduced and compaction of sludge for filtration can be accomplished by stopping the process every 2 to 3 hr. and allowing the tanks to rest for the same time. This creates operational problems and cuts production.

The cause of loss of solids by elutriation has not been specifically determined. There is a high percentage of fines that settle under quiescent conditions but go over the effluent weirs under continuous flow conditions. Their density and volatile matter content are practically the same as that of the coarser material. Refusal of the solids to settle and compact is probably due to their colloidal nature.

Free oil floats out of the tanks with the wash water. Sludge from the bottom of the secondary digester contains about 16 per cent grease. Elutriated sludge contains about 14 per cent, so approximately 12.5 per cent of the grease is removed by washing. The grease removed is mostly hydrocarbons in the form of mineral oil.

The settling tanks originally had no baffles. Each tank has an influent channel 2½ ft. wide by 1 ft. high. These inlets are located in the centers of the inlet ends, with flow depth being 9 in. Normal wash-water sludge flows of 120 g.p.m. produce entrance velocities of 8.5 ft. per minute. Such surface velocity causes tank short-circuiting, which can be observed with dye testing. The tanks have normal working depths of 12 ft. and theoretical settling times of 6.3 hr. with a feed rate of 120 g.p.m., but surface flow-through time is of the order of 10 to 15 min. This happens in spite of the fact that the surface settling rate is only 346 gal. per square foot per day and the tanks are 40 ft. long.

A target baffle, 5 ft. by 5 ft., was installed 1 ft. in front of each inlet port to reduce shirt-circuiting. This caused some improvement by dispersing the influent. Then an 8-ft. by 11-ft. wide slotted baffle was hung 2 ft. in front of one inlet to distribute flow across the tank's cross-section and eliminate surface short-circuiting. Four horizontal slots of 2, 4, 6, and 12 in. were left at increasing depths to accomplish even distribution. This baffle also affected some improvement, but not enough to permit design rates of operation. At present, thought is being given to the idea of installing one or more baffles of a venetian blind type, which has proven successful in similar operations.

It should be mentioned that original design called for elutriation of digester supernatant. This operation was unsuccessful from the start because supernatant had to be pumped at a 200-

g.p.m. rate. This stirred up the elutriation tank contents and produced bad results. Consequently, supernatant was soon diverted directly to the plant influent.

Chemical Coagulation

Sludge coagulation has presented no particular problems and operational control is good. The main difficulty occurs when sludge concentration is changing rapidly and sludge solids data cannot be obtained fast enough to keep the ferric chloride dosage at the right level. Relatively slow agitator speeds of 3 to 4 r.p.m. are most satisfactory.

Operational records do not agree with ferric chloride dosages calculated by Genter's formulas (18). Average operational results are compared with calculated values in Table I. Operational ferric chloride dosage is based only on operational experience, but the ratio of operational dosage to calculated dosage holds at about 2 to 1.

TABLE I.—Chemical Conditioning of Sludge, Little Miami Sewage Works, Average Yearly Values

Item	1954	1955	1956
Sludge:			
Alkalinity (p.p.m.)	610	680	670
Solids (%)	8.1	7.2	6.2
Volatile matter (%)	41.7	47.4	48.6
$FeCl_3$ dosage, feed rate (%)	3.7	5.1	5.9
Calculated $FeCl_3$ dosage, Genter:			
Liquid demand (%)	0.75	0.95	1.10
Solids demand (%)	1.15	1.44	1.51
Total demand (%)	1.90	2.39	2.61
Ratio (act. dosage/calc.)	1.95	2.13	2.26

Laboratory Studies

Laboratory results have proven beneficial in evaluating filtration and conditioning variables. It is relatively easy

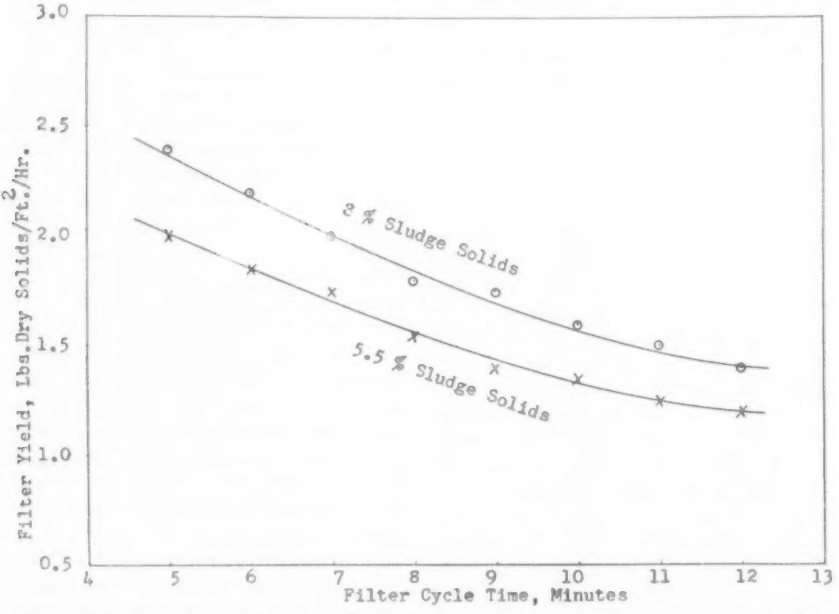

FIGURE 4.—Filter leaf test, effect of drum speed and solids concentration on filter yield; elutriated, digested sludge, Little Miami plant. Ferric chloride dosage, 5 per cent; vacuum, 25 in. Hg.

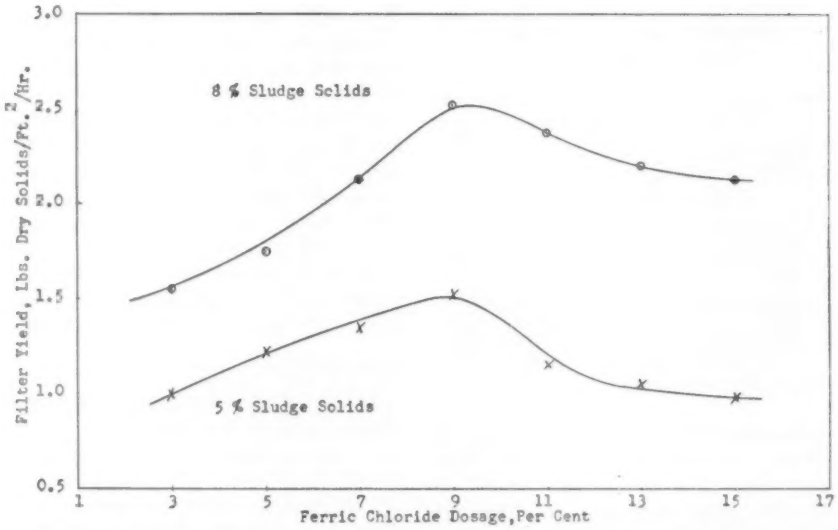

FIGURE 5.—Filter leaf test, effect of ferric chloride dosage and sludge solids concentration on filter yield; elutriated, digested sludge, Little Miami plant. Drum speed, 12-min. cycle; vacuum, 25 in. Hg.

to control factors and measure parameters.

Filtration

Filter yield and cake moisture, as stated earlier, are the important criteria. The former assumes prime importance because filter capacity is limited but incinerator capacity is ample.

The filter leaf test is preferred to the Buchner funnel test because it simulates drum filter operation and permits yield results comparable to plant operations. Figure 4 shows that yield is directly proportional to drum speed and sludge concentration. The relation between yield and drum speed is logarithmic and a log-log plot would produce a straightline curve. The yield versus sludge concentration curve would be a straight line.

Figure 5 shows the relation between ferric chloride dosage and filter yield. This confirms the opinion that there is an optimum value for ferric chloride dosage somewhere between too little and too much. The current price of ferric chloride dictates cost per unit of production, however.

Cake moisture is a function of filter vacuum, chemical dosage, and drum speed. Filter vacuum is maintained at 25 to 27 in. Hg, which is optimum for both cake moisture and filter yield. Drum cycle times were varied from 5 to 12 min., and ferric chloride dosages from 2 to 15 per cent. Inconsistent cake moisture results were obtained on the leaf filter, although cake moisture only varied from 62 to 67 per cent. Longer cycle times tended to give lower cake moistures, but the effect of ferric chloride was inconclusive.

Elutriation

Elutriation reduces sludge alkalinity from about 2,700 p.p.m. to about 700 p.p.m. with 300- to 350-p.p.m. well water and to about 350 p.p.m. with 90- to 110-p.p.m. city water. Elutriation with city water produces a cleaner elutriate than with well water, and also a heavier sludge for filtration. Monthly and yearly sludge yields show more solids to elutriation than to filtration,

TABLE II.—Effect of Ferric Chloride on Elutriation Settling; Concentration of Washed Sludge, 3.1 Per Cent Dry Solids

$FeCl_3$ Dosage (p.p.m.)	Suspended Solids in Elutriate (%)				Total Solids After 300 Min. (%)
	15 Min.	30 Min.	90 Min.	300 Min.	
2,000	0.010	0.003	0.009	0.013	—
1,000	0.011	0.014	0.001	0.026	3.69
750	0.013	0.007	0.008	0.013	—
500	0.021	0.006	0.008	0.033	3.83
350	0.035	0.031	0.007	0.032	3.95
250	0.038	0.042	0.016	0.032	4.00
0	0.113	0.086	0.058	0.052	4.07

indicating loss or recycling through the plant. Individual daily results, however, show that compaction can be obtained during elutriation, even though dirty effluents may result.

Some effort was made in the laboratory to effect better separation of water and solids in the elutriation settling tanks. Much of the sludge solids is of a colloidal nature; therefore, thought was given to neutralization of particle charge to effect coagulation and sludge compaction. Sludge solids are negatively charged.

Varying amounts of ferric chloride were added to 500-ml. volumes of the sludge-water mixture from the elutriation mixing tank. Suspended solids determinations were run on the supernatant from 500-ml. graduates over time periods up to 5 hr. Total solids were run on the sludge after 5-hr. settling. The results (Table II) show that ferric chloride with settling produces a cleaner supernatant and slightly less compaction than settling without the coagulant. They also show that increasing concentrations of ferric chloride produce cleaner supernatants, but decreasing compaction. Alum also will coagulate the sludge solids to produce a clear supernatant, but compaction is practically zero.

Neutralization of the colloidal particle charge with acid makes for good compaction at the iso-electric point. No fluffy chemical precipitates are formed with the sludge. Data indicate that the iso-electric point is about at pH 5.5. The 24-hr. compaction of digested sludge was 16 per cent at pH 6.0, 64 per cent at pH 5.5, and 23 per cent at pH 5.0. Cost of sulfuric acid would be about $50.00 per day and there would be the problems of handling and corrosion.

A scale model of the elutriation tanks has been built to permit study of operational variables and baffling.

Chemical Coagulation

It takes 25 to 30 min. for coagulated sludge to reach the filter cloths. Tests were run on coagulated sludge to show the effect of time. The data are given in Table III. The Lebanon sludge showed a definite decrease in filter yield with increasing time but such was not the case with Little Miami and Loveland sludges.

Sludge Characteristics

The effects of sludge characteristics on coagulation and filtration are difficult to measure and evaluate. Limited

TABLE III.—Effect of Coagulant Contact Time on Filter Yield (Ferric Chloride Dosage, 7 per cent; Vacuum, 26 in. Hg; Drum Speed, 12-Min. Cycle)

Time (min.)	Yield (lb./sq. ft./hr.)			
	Little Miami[1]	Little Miami[2]	Loveland[3]	Lebanon[4]
0	1.57	2.05	0.82	2.68
20	2.06	2.21	0.90	1.86
40	1.79	2.40	0.95	1.24
60	1.36	2.02	0.86	1.12

[1] Secondary digester, primary treatment; total solids = 9.7 per cent, alkalinity = 470 p.p.m.

[2] Tertiary digester, primary treatment; total solids = 10.9 per cent, alkalinity = 600 p.p.m.

[3] Secondary digester, secondary treatment-trickling filter; total solids = 6.3 per cent, alkalinity = 500 p.p.m.

[4] Primary digester, secondary treatment-activated sludge; total solids = 9.8 per cent, alkalinity = 650 p.p.m.

data have been obtained at Little Miami, but they indicate reasons for certain operational results.

Particle Size

Microscopic examination of sludges reveals a great number of fines. Average total field counts show that 76 per cent of the raw sludge solids, 85 per cent of the primary digester solids, and 84 per cent of the secondary digester solids were less than 5 microns in cross section. Likewise, 12.6 per cent of the raw sludge solids, 2.6 per cent of the primary digester solids, and 2.1 per cent of the secondary digester solids were over 100 microns in cross section. The small remaining percentages were between these two sizes. Practically all the particles over 100 microns in size were fibers. These percentages represent numbers of particles, not masses or volumes.

These results indicate that much of the sludge solids is colloidal or near colloidal size. Consequently, there is great surface area per unit mass. Moreover, the organic matter, which constitutes about 50 per cent of the solids, probably has capillary surfaces holding great quantities of water. This may explain why the sludge settles with difficulty in elutriation settling tanks and resists compaction. This also helps to explain why Genter's equations for determining chemical coagulant demands give low results. Finally, these fines may contribute to filter blinding.

Nature of Solids

The volatile matter test gives an approximation of organic matter. Volatile matter of sludge from digestion to elutriation varies from 41 to 53 per cent, with an average of 47 per cent. Low values occur in warm weather, high in cold. Elutriation has little if any effect on these values.

It is difficult to say how much of the colloidal dispersion of the sludge is of the suspensoid type and how much is of the emulsoid type. Dehydration of the sludge indicates a large amount to be suspensoid, because it cannot be redispersed in water. Whatever emulsoid is present is probably organic matter. This emulsoid may account for the reversion of chemically coagulated sludge on standing before filtration.

Genter's statement (2) that compressibility of sludge solids is a direct function of organic matter in the solids is probably true. However, the statement that the amount of coagulants used must be a function of volatile matter ignores all the inorganic matter which may be colloidal.

Specific Gravity of Sludge

Digested sludge to elutriation and filtration has a specific gravity of about 1.02. The specific gravity of inorganic solids is approximately 2.71, of organic solids about 1.36, with a combined value of 1.62 to 1.78 for total sludge solids. These values are consistent with sludge values of 6 to 8 per cent solids and 47 per cent volatile matter and do not indicate anything unusual about the sludge.

Grease in Sludge

Raw sludge to digestion contains 16 to 20 per cent grease (19). Settling tank skimmings to digestion contain 78 per cent grease but constitute less than 1 per cent of solids to digestion. Grease content drops to 14 to 16 per cent in digested sludge. Elutriation then reduces grease content to 13 to 15 per cent of dry solids.

Microscopic examination of raw sludge shows oil droplets mixed in with the solids particles. Digested sludge has very few oil droplets, elutriated sludge practically none. This can be explained by the fact that glycerides and fatty acids are broken down by digestion and the stable hydrocarbons rise to tops of digesters on quiescent settling. Considerable mineral oil accumulates in the tops of the digesters and is periodically removed. Practi-

cally all the free oil in the digested sludge to elutriation is floated out of the sludge in the elutriation settling tanks. This means that the bulk of the grease is adsorbed on the solids. This affects chemical coagulation for filtration.

Grease in sludge may be placed in three classes—hydrocarbons, fixed oils or glycerides, and fatty acids. Separation may be accomplished in a chromatographic column using acid-washed alumina and the proper solvents. Carbon tetrachloride will remove hydrocarbons; ethyl alcohol, the fixed oils or oxidized hydrocarbons; and ethyl alcohol, acidified with acetic acid, the fatty acids. Saponification will separate hydrocarbons from the other materials.

Raw sludge contains about 55 per cent hydrocarbons, 27 per cent fixed oils or glycerides, and 18 per cent fatty acids. Anaerobic digestion changes the values to about 80 per cent hydrocarbons, 18.5 per cent fixed oils or glycerides, and 1.0 per cent fatty acids. Practically all the fatty acids, part of the fixed oils or glycerides, and none of the hydrocarbons are broken down by anaerobic digestion. Consequently, the relative percentage of hydrocarbons goes up from 55 to 80 per cent during digestion. The effects of these components on coagulation and filtration are not presently known.

Grease content and its components vary with the source of sewage and methods of treatment. Digested sludge from the small Loveland, Ohio, plant, receiving only domestic sewage and having a trickling filter, had a grease content of only 4.0 per cent. Separation showed about 49 per cent hydrocarbons, 47 per cent fixed oils or glycerides, and no fatty acids.

Resistance to Filtration

The parameter "specific resistance," developed by Coackley and Jones (10), measures the filterability of sewage sludges and can be expressed in reproducible numerical values. It is based on use of a Buchner funnel, so accurate yield values are not possible. Their equation for resistance is

$$r = 2P\ A^2b/uc$$

where r is specific resistance in centimeters per gram; P is pressure in grams per square centimeter; A is area in square centimeters; u is viscosity of filtrate in poises; c is the ratio of grams dry cake solids per gram of liquid in the sludge before filtration; and b is

TABLE IV.—Specific Resistance Values for Sludges

Elutriated	Vacuum (in. Hg)	$FeCl_3$ (%)	Specific Resistance (cm./g.)		
			Little Miami[1]	Loveland[2]	Lebanon[3]
No	7	0	1.3×10^9	3.8×10^9	7.2×10^9
No	25	0	—	1.5×10^{10}	—
No	7	5	2.2×10^8	1.5×10^9	—
No	7	10	1.4×10^8	—	3.0×10^8
No	25	10	3.0×10^8	—	—
Yes	7	0	1.0×10^9	—	7.0×10^9
Yes	7	2	2.4×10^8	—	—
Yes	7	5	1.3×10^8	2.4×10^8	—
Yes	7	10	1.3×10^8	—	1.2×10^8
Yes	25	0	2.1×10^9	—	—
Yes	25	5	1.3×10^8	—	—

[1] Primary and secondary digesters, primary treatment.
[2] Primary digester, secondary treatment with trickling filter.
[3] Primary digester, secondary treatment with activated sludge.

the slope of the graph of θ/V, where V is the volume of filtrate and θ is the time in seconds.

Table IV shows values for r with Little Miami sludge and two other digested sludges. Specific resistance values show that (a) pressure increases resistance slightly, (b) ferric chloride has greatest effect in reducing resistance either with elutriated or unelutriated sludge, (c) elutriation reduces resistance slightly, and (d) increasing ferric chloride over 2 per cent decreases resistance slightly. It is interesting to note that specific resistance of digested sludge with no ferric chloride increases with the order of treatments: primary, secondary with trickling filter, and secondary with activated sludge. Use of ferric chloride produces about the same r-values with all three sludges.

Summary and Conclusions

1. The principles of sludge conditioning and filtration are briefly discussed.

2. Facilities for disposal of digested sludge at Cincinnati's Little Miami sewage works are described.

3. Operational data show that filtration results do not meet the design standards. This is largely due to sludge solids loss from the elutriation tanks. Good filtration yields with little filter cloth blinding can be obtained with 8 per cent and more solids, but such results are not possible when solids losses in elutriation run as high as 25 per cent. Filter cloths show little blinding with cake ¼ in. and more thick, which can be obtained with 8 per cent and more sludge solids.

4. Plant studies show that filter yield is directly proportional to drum speed and sludge concentration, the relation with drum speed is logarithmic, and with sludge concentration it is straight-line. Further study of filter cloths and baffling in elutriation tanks is needed.

5. Laboratory studies are helpful in controlling and evaluating plant operations. The filter leaf test is preferred to the Buchner funnel test because it permits filter yield results comparable to plant operations. The direct relations between yield and drum speed and between yield and sludge solids concentration can also be demonstrated with the filter leaf test. Filter yield increases with increasing ferric chloride dosage to a maximum and then decreases.

Study of sludge conditioning for filtration shows need for further work. The filterability of some chemically coagulated sludges decreases with time but this is not indicated with Little Miami sludge. Additions of ferric chloride or alum to sludge for elutriation produces cleaner supernatants but less compaction. Neutralization of colloidal particle charge with sulfuric acid effects good compaction at pH 5.5.

Study of sludge characteristics helps to explain sludge conditioning and filtration problems. Most sludge particles are colloidal or near colloidal size. Most of the grease in elutriated, digested sludge is composed of hydrocarbons which are adsorbed on the sludge particles. The effects of this oil on coagulation and filtration are not known. The resistance of sludge to filtration and its compressibility can be measured in the laboratory and expressed in reproducible numerical units.

Acknowledgments

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CORRECTION

In the 1956 Critical Review of Literature under Industrial Wastes, Food Processing Wastes, page 614, the cost of lagooning cannery wastes should be \$0.006 to \$0.007 per case and not \$0.06 to \$0.07.

SAMPLING PROCEDURE FOR TANKS OF HOMOGENEOUS CONTENT

By Peter J. Neuspiel*

Research Associate, State University of Iowa, Iowa City, Iowa

The effectiveness of a sewage treatment unit is measured quantitatively by B.O.D. removal, solids removal, volatile solids destruction, etc.

If the flow through the unit is laminar, that is, relatively free of disturbances, the obtaining of samples that indicate the degree of treatment is relatively simple.

If, on the other hand, the contents of the treatment tank are subjected to continuous mixing resulting in a homogeneous mixture, the sampling of the influent and effluent in order to measure accurately the effectiveness of treatment becomes involved.

Due to the considerable number of samples which must be taken, the following procedure was developed on a mathematical basis to provide a method to accurately measure the effectiveness of treatment. By utilizing this procedure, fewer samples are required and a more accurate measurement can be obtained.

Mathematical Analysis

It is assumed that a treatment tank of volume, V, is subjected to continuous mixing and has an equal rate of inflow and outflow.

$$q_{in} = q_{out} = q$$

At time $T = 0$, the tank is full of a homogeneous liquid of unknown composition. At $T = 0$ the sampling of the influent liquid is begun. At any time, $T = t$, after the beginning of sampling, the volume of sampled liquid, X, added to the tank will be $X = qt$.

The volume of sampled liquid in the tank is indicated by S, the volume of sampled liquid in any part of the tank, ΔV, will be $\frac{S}{V}\Delta V$.

If a small volume, ΔP, of the tank contents leaves the tank, the volume of sampled liquid in the volume ΔP will be $\frac{S}{V}\Delta P$.

During the time that this volume of sampled liquid leaves the tank, a volume equal to ΔP of sampled liquid enters the tank so that the net change in volume of sampled liquid in the tank will be

$$S = \Delta P - \frac{S}{V}\Delta P$$

$$\frac{\Delta S}{\Delta P} = 1 - \frac{S}{V}$$

As P approaches zero, the instantaneous rate of change of S with respect to P is obtained.

$$\frac{ds}{dp} = 1 - \frac{S}{V}$$

$$dp = \frac{ds}{1 - \frac{S}{V}}$$

Let

$$f = 1 - \frac{S}{V}$$

$$df = -\frac{1}{V}ds$$

$$ds = -Vdf$$

$$dp = -\frac{Vdf}{f}$$

* Presently, Sanitary Engineer, Chicago Pump Company.

Solving this differential equation yields

$$P = V \ln f + K$$

$$P = V \ln \left(1 - \frac{S}{V}\right) + K$$

If $P = 0$ when sampling is begun, $K = 0$, and $P = X$.

Then $\frac{X}{V} = N$, the number of tank displacements since the beginning of sampling at $T = 0$, and

$$N = \ln \left(\frac{V}{V - S}\right)$$

$\frac{S}{V} \times 100$ = percentage of sampled liquid in the total volume, V, of the tank.

The percentage of sampled liquid in the tank at any time after start of sampling is

$$\frac{100\ (e^N - 1)}{e^N}$$

This equation is solved for various values of N:

N	Per Cent
1	63
2	86
3	95
4	98
5	99
6	→100

Example

A 10,000-gal. tank is filled with unsampled liquid. Liquid enters and leaves the tank at a rate of 1,000 g.p.d. The tank undergoes continuous mixing so that at any time the content is homogeneous.

The displacement (or detention time) of the tank is

$$T = \frac{V}{q} = \frac{10{,}000 \text{ gal.}}{1{,}000 \text{ g.p.d.}} = 10 \text{ days}$$

If at $T = 0$, the influent liquid is begun to be sampled, at $T = 10$ days or $N = 1$, 63 per cent of the tank volume will consist of sampled liquid. At $T = 30$ days, $N = 3$, 95 per cent of the tank volume, as well as the effluent, will consist of sampled liquid. As the sampling duration is increased, the percentage of sampled liquid in the effluent approaches 100 per cent, asymptotically.

Application

This method is applicable to any flow-through process in which the treatment tank contents are homogeneous.

In a tank with a detention time of several days or weeks, such as a digester of homogeneous content, this method can be employed for accurately determining the volatile solids destruction.

In order to obtain meaningful results, the following data should be obtained daily for three displacement periods:

1. Volume of raw sludge added.
2. Total solids added.
3. Volatile solids added.

The multiplication factors for the three displacements are:

1st	0.10
2nd	0.24
3rd	0.66

After raw sludge has been sampled for three displacement periods, a digester survey to determine the total solids and the volatile solids contents of the digester should be made.

The difference between the weighted average of the volatile solids added during the three displacement periods and the volatile contents of the digester at the end of three displacements gives the volatile solids destroyed.

Example

If 200 lb. of volatiles are added during the first displacement, 400 lb. during the second, and 300 lb. during the third, the sludge in the digester at the end of the third displacement would contain the following amount of volatile solids if there was no destruction.

200 lb. × 0.10 = 20.0 lb.
400 lb. × 0.24 = 96.0 lb.
300 lb. × 0.66 = 198.0 lb.
Total = 314.0 lb.

If the digester contains 170 lb. of volatile solids at the end of three displacements, the destruction is

$$314 \text{ lb.} - 170 \text{ lb.} = 144 \text{ lb.}$$

The solids added can be obtained by keeping a record of the volume of sludge pumped and analyzing samples of this sludge for total and volatile solids. Calculations would be:

$$\text{Pounds volatile solids added} = \text{gallons pumped} \times 8.33 \text{ lb.} \times \frac{\text{per cent total solids}}{100} \times \frac{\text{per cent volatile solids}}{100}$$

$$\text{Pounds volatile solids in digester} = \text{volume of digester (gal.)} \times 8.33 \times \frac{\text{per cent total solids}}{100} \times \frac{\text{per cent volatile solids}}{100}$$

If the detention time of the treatment unit is of relatively short duration, such as a preaeration unit, the method can be modified. For example, it is desired to determine the B.O.D. removal accomplished in a preaeration tank. Influent samples are collected separately for three displacement periods. At the end of three displacements, a sample of the effluent is taken. The three influent samples should be volumetrically composited. If the total volume of the samples is assumed to be unity, it should be made up as follows:

0.10 volume from the first displacement.
0.24 volume from the second displacement.
0.66 volume from the third displacement.

By determining the B.O.D. of this composited influent sample, and the B.O.D. of the effluent sample, the effectiveness of treatment may be accurately determined.

MEETINGS OF INTEREST

1957

Dec. 8–11 **American Institute of Chemical Engineers,** Annual Meeting, Conrad Hilton Hotel, Chicago, Ill. F. J. Van Antwerpen, Secretary, 25 West 45th St., New York, N. Y.

1958

Jan. 27–31 **Missouri Water and Sewage Works Training Courses,** University of Missouri, Columbia, Mo. Professor L. T. Murphy, College of Engineering, University of Missouri, Columbia, Mo.

Feb. 26–28 **American Society of Civil Engineers,** Sherman Hotel, Chicago, Ill. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.

Mar. 17–21 **Fourth Nuclear Engineering and Science Conference,** International Amphitheatre, Chicago, Ill.

Apr. 18 **Annual Pennsylvania Clean Streams Conference,** Penn-Harris Hotel, Harrisburg, Pa. Pennsylvania State Chamber of Commerce, Harrisburg, Pa.

Apr. 20–25 **American Water Works Association,** Dallas, Texas. Harry E. Jordan, Secretary, AWWA, 2 Park Ave., New York 16, N. Y.

ACTIVATED SLUDGE CULTURES DEVELOPED ON PURE ORGANIC COMPOUNDS

By Richard S. Engelbrecht and Ross E. McKinney

Respectively, Research Assistant Professor of Sanitary Engineering, University of Illinois, Urbana, Ill., and Assistant Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

In recent years there has been an increasing interest in the metabolism of pure organic compounds by biological waste disposal methods. It is believed by many investigators that not only will such information contribute valuable fundamental knowledge regarding the biochemistry of biological systems having a heterogeneous population, but will also be useful in evaluating the treatability of various industrial wastes.

One of the first investigations made using a pure organic compound was that carried out by Ruchhoft and his co-workers in 1940 (1)(2). While studying the metabolism of glucose by activated sludge, they made a number of important observations, one of which was the significance of acclimation. Since then there have been a number of studies made which showed that a period of acclimation or adaptation was necessary for optimum efficiency of biological systems (3)(4)(5)(6).

From research on the utilization of various organic substrates by activated sludge, Placak and Ruchhoft (3) concluded that the rate of biochemical change was a function of the individual compound rather than of the class to which the compound belonged. Later Mills and Stack (7), using acclimated non-flocculent aerating cultures, found that biological oxidation of pure compounds was related to the chain structure, molecular size, and the functional groups present in the molecule. The significance of chemical structure as related to acclimation and metabolism has also been observed by other investigators (8)(9).

The data presented here are part of a study made on the energy relationships in activated sludge cultures. However, this paper is concerned only with the relationship that exists between the predominating organisms in activated sludge, the chemical structure of the organic substrate, and the pathway through which it is metabolized.

Laboratory Procedures

Activated sludge systems were developed in the laboratory using pure organic compounds as the sole source of energy. Sufficient inorganic salts were added to the organic substrates to produce a nutritionally balanced system for the optimum production of protoplasm. The organic compounds chosen for study were based on the three major groups of organic compounds found in sewage—carbohydrates, proteins (amino acids), and fats (organic acids). The organic compounds and their empirical formulae are listed in Table I.

The laboratory activated sludge units were operated on a fill-and-draw basis, using 1.5-l. tubes. The systems were maintained in a constant temperature water bath at 20° C. Each unit was initially started with 1.4 l. of substrate containing 333 mg. of organics per liter and 100 ml. of settled domestic sewage for seed microorganisms. Air was supplied to the unit by compressed air at 10 p.s.i. through a carborundum dif-

TABLE I.—Pure Chemical Compounds Used to Develop Activated Sludges

Carbohydrates:

Pentose: $C_5H_{10}O_5$
Arabinose
Xylose

Hexose: Monosaccharides $C_6H_{12}O_6$

Glucose
Galactose
Mannose

Hexose: Disaccharides $C_{12}H_{22}O_{11}$

Sucrose (Glucose-Fructose)
Maltose (Glucose-Glucose)
Lactose (Glucose-Galactose)

Amino Acids:

Glycine: $CH_2NH_2 \cdot COOH$
Alanine: $CH_3 \cdot CHNH_2 \cdot COOH$
Valine: $(CH_3)_2 \cdot CH \cdot CHNH_2 \cdot COOH$
Leucine: $(CH_3)_2 \cdot CH \cdot CH_2 \cdot CHNH_2 \cdot COOH$
Threonine: $CH_3 \cdot CHOH \cdot CHNH_2 \cdot COOH$
Glutamic Acid: $COOH \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$
Phenylalanine: $C_6H_5 \cdot CH_2 \cdot CHNH_2 \cdot COOH$
Tryptophane: $C_8H_5NH \cdot CH_2 \cdot CHNH_2 \cdot COOH$
Arginine: $NH_2 \cdot CNH \cdot NH \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$
Methionine: $CH_3 \cdot S \cdot CH_2 \cdot CH_2 \cdot CHNH_2 \cdot COOH$

Organic Acids:

Formic Acid: $HCOOH$
Acetic Acid: $CH_3 \cdot COOH$
Valeric Acid: $CH_3 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot COOH$
Caproic Acid: $CH_3 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot COOH$
Heptanoic Acid: $CH_3 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot CH_2 \cdot COOH$
Benzoic Acid: $C_6H_5 \cdot COOH$

fuser. The air was not measured or controlled beyond supplying sufficient air to always maintain the activated sludge in suspension. Previous laboratory studies had shown that such aeration provided more oxygen than could be transferred or used with these organic concentrations.

The activated sludge systems were allowed to aerate for 23 hr., after which 0.5 l. of the mixed liquor was wasted. The remaining 1.0 l. of mixed liquor was allowed to settle for 1 hr. and 0.5 l. of the supernatant was drawn off and discarded. One liter of fresh substrate containing 333 mg. of organics was added to each unit and aeration was started. Thus, the units were operated so that one-third of the sludge was wasted at each feeding; this maintained the microbiological population in an active state. The low organic content of the substrate at the start of the aeration period, approximately 222 mg. per liter, insured rapid utilization of the organic matter.

After 15 days operation, hourly samples of the mixed liquor were withdrawn for analysis, beginning with the 23rd-hr. sample on the 15th day and continuing through the 8th hour of aeration after feeding. The suspended or biological solids in the mixed liquor were determined by the membrane filter technique described by Engelbrecht and McKinney (10). The filtrate was collected and analyzed for 5-day B.O.D. and dichromate chemical oxygen demand (C.O.D.) in accordance with "Standard Methods" procedures (11).

All of the substrates were soluble and readily passed through the membrane filter unless adsorbed or metabolized by the activated sludge. Thus, these techniques provided a good measure for determining the change in solids due to both adsorption and metabolism, and the unmetabolized substrate. These analyses were repeated after 23 days of operation to determine the effect of additional acclimation to the individual organic compounds. There were no changes in metabolism between runs on the 15th day and the 23rd day.

Biochemical Changes

Because of the similarity of the biochemical changes that occurred in many of the activated sludge systems, only a few of the more representative systems will be shown graphically. These data are shown in Figures 1 through 7 and indicate only the changes that occurred during the 8-hr. aeration period following feeding. Because many of the systems were still in an active state of metabolism at the end of this period, a more complete

table showing the changes after 23 hr. of aeration is included for all of the systems studied. These data are shown in Table II. Photomicrographs were taken of the sludge developed in each culture in order to have a permanent record; however, only a brief description of them will be presented in this discussion.

The carbohydrates studied included arabinose, xylose, glucose, mannose, fructose, galactose, lactose, maltose, and sucrose. The biochemical changes that ocurred with xylose, a pentose sugar, on the 16th and 23rd days following the initiation of the culture are shown in Figures 1 and 2. The data for both days were similar in that the maximum solids concentration occurred after 6 hr. of aeration, while most of the xylose was removed from solution during this same period. The sludge of this culture was found to be very dense, with many bacteria at the periphery. Filamentous type organisms were not observed. The biochemical changes and sludge appearance for the system developed on arabinose, another

TABLE II.—Biochemical Data on Various Activated Sludge Systems After 23 Hr. of Aeration

Substrate	16th Day				23rd Day			
	Mixed Liquor Solids (mg./l.)	Effluent 5-Day B.O.D. (mg./l.)	Solids Increase per Day (mg./l.)	B.O.D. Reduction (%)	Mixed Liquor Solids (mg./l.)	Effluent 5-Day B.O.D. (mg./l.)	Solids Increase per Day (mg./l.)	B.O.D. Reduction (%)
(*a*) Carbohydrates								
Arabinose	224	4.3	75	97	214	1.9	71	99
Xylose	—	—	—	—	234	3.1	78	98
Glucose	298	2.5	100	98	—	—	—	—
Galactose	260	2.5	87	98	—	—	—	—
Mannose	266	1.2	89	99	—	—	—	—
Fructose	272	3.7	91	97	—	—	—	—
Sucrose	388	6.2	129	95	388	—	129	—
Maltose	—	—	—	—	250	3.7	83	98
Lactose	—	—	—	—	312	6.2	104	95
(*b*) Amino Acids								
Glycine	124	6.2	41	93	144	—	48	—
Alanine	220	5.0	73	97	244	5.6	81	96
Valine	318	4.3	106	99	312	0.6	104	99
Leucine	440	3.7	147	99	434	5.6	144	98
Threonine	214	13	71	91	214	4.3	71	98
Glutamic Acid	178	8.1	59	95	204	6.8	68	96
Phenylalanine	376	4.3	125	99	388	2.5	113	99
Tryptophane	288	1.9	96	99	298	1.9	99	99
Arginine	238	8.7	79	94	234	10	71	94
Methionine	166	29	55	80	144	28	48	80
(*c*) Organic Acids								
Formic Acid	60	21	20	—	52	1.2	17	95
Acetic Acid	230	1.2	77	99	214	1.9	71	99
Valeric Acid	376	2.5	125	99	348	5.6	116	98
Caproic Acid	458	2.5	153	99	464	6.8	155	98
Heptanoic Acid	530	3.1	177	99	494	3.1	165	99
Benzoic Acid	370	1.2	123	99	340	1.9	113	99

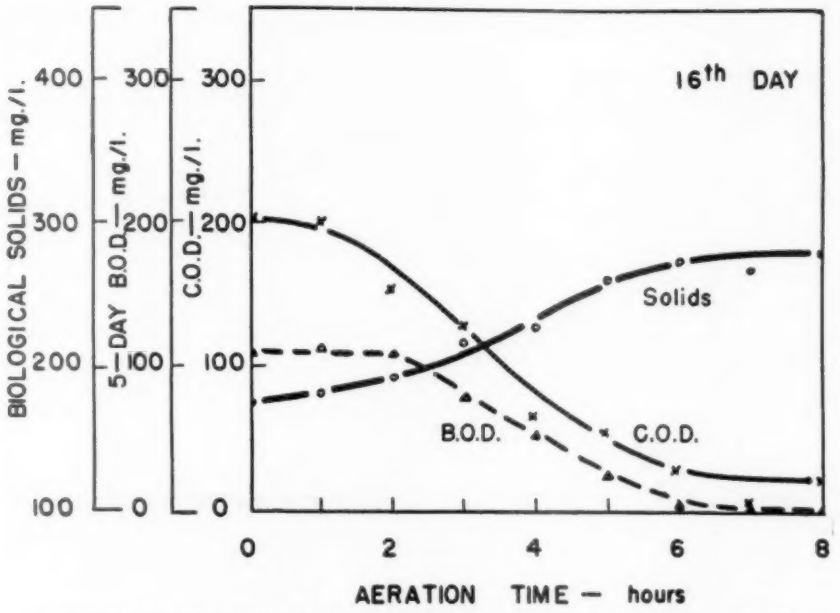

FIGURE 1.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of xylose.

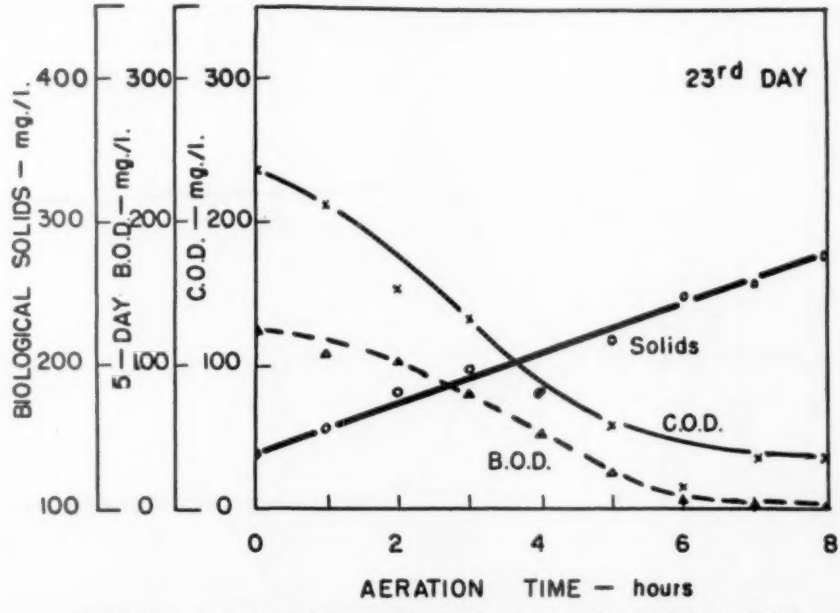

FIGURE 2.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of xylose.

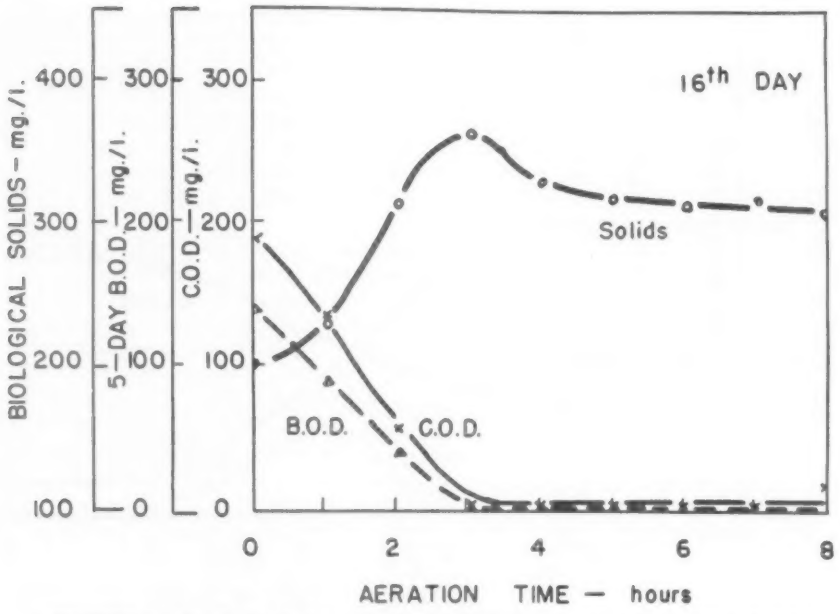

FIGURE 3.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of glucose.

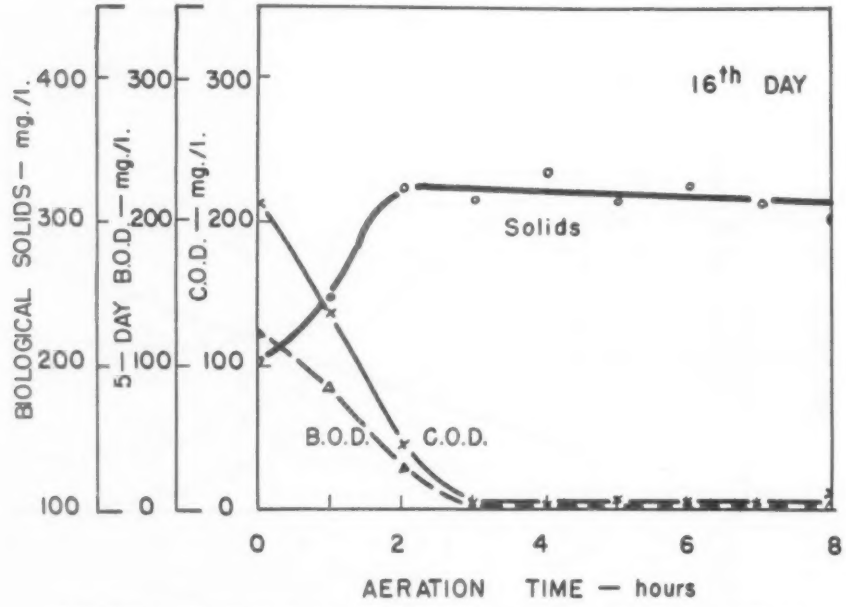

FIGURE 4.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of fructose.

pentose sugar, were identical to that of the xylose system.

Figure 3 shows the changes which occurred in the glucose culture on the 16th day following initiation of the culture. Essentially, all of the glucose had been removed from the solution and the maximum sludge mass had been reached after 3 hr. of aeration. The sharp decrease in solids that followed has been shown to be the result of metabolizing the glucose absorbed into the microorganisms in the solids. The changes that occurred with fructose as the organic substrate (Figure 4) were similar to those found for glucose. The sludges of both cultures were similar in appearance in that both showed the predominance of a large filamentous type organism.

The data for the lactose and sucrose cultures are shown in Figures 5 and 6 for the 23rd day after initiation of the culture. The biochemical changes in these two cultures showed a striking similarity in that practically all of the organic substrate was removed and the maximum solids concentration was reached by the third hour. The sludges developed in these two systems were found to be different in appearance. The lactose sludge consisted largely of a filamentous type organism while the sludge of the sucrose culture was made up predominantly of bacteria, existing either in clumps or as individual cells. These bacterial cells possessed a large amount of capsular material.

The amino acids studied were selected so that there was at least one representative from each chemical class. Included were glycine, alanine, valine, leucine, threonine, arginine, glutamic acid, methionine, phenylalanine, and tryptophane. In general, the biochemical changes that occurred in these cultures were similar to those shown for the carbohydrates, while the morphological appearances of the sludges were quite different.

Figure 7 shows the changes that oc-

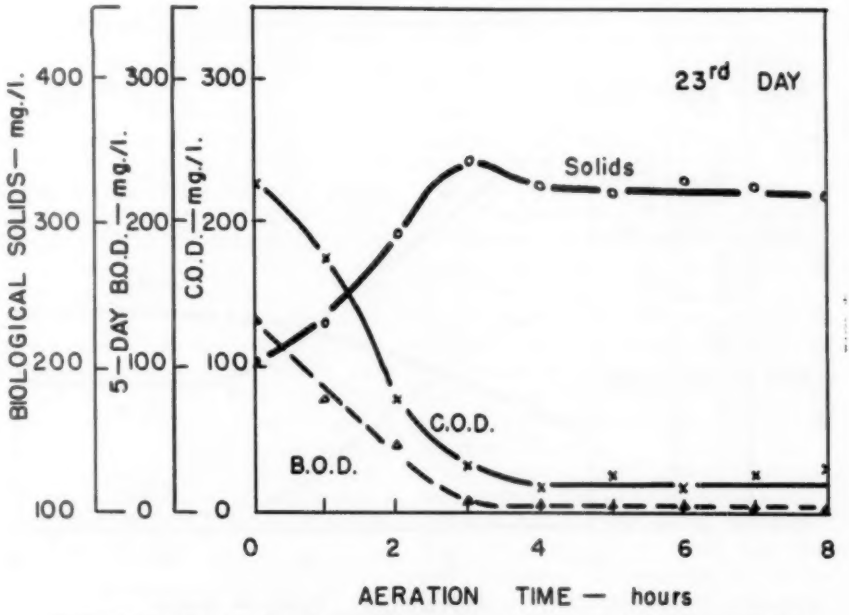

FIGURE 5.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of lactose.

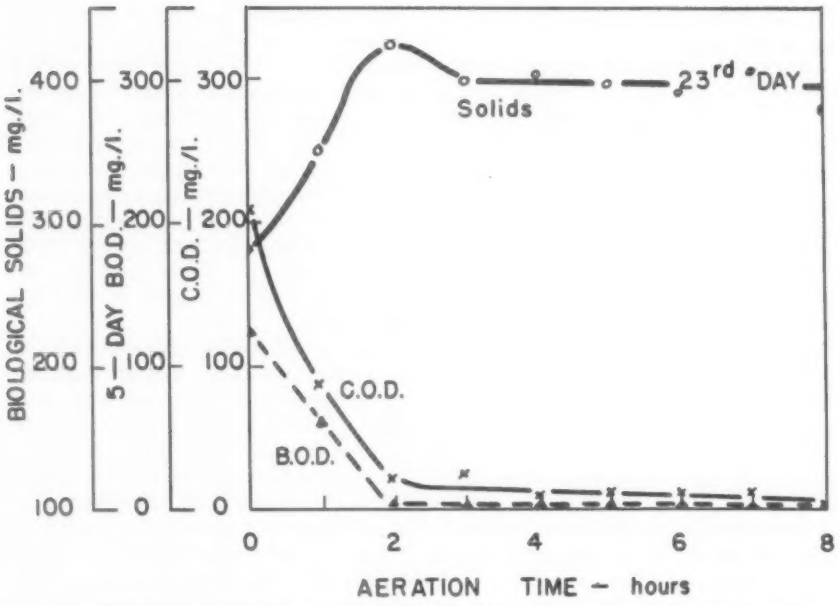

FIGURE 6.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of sucrose.

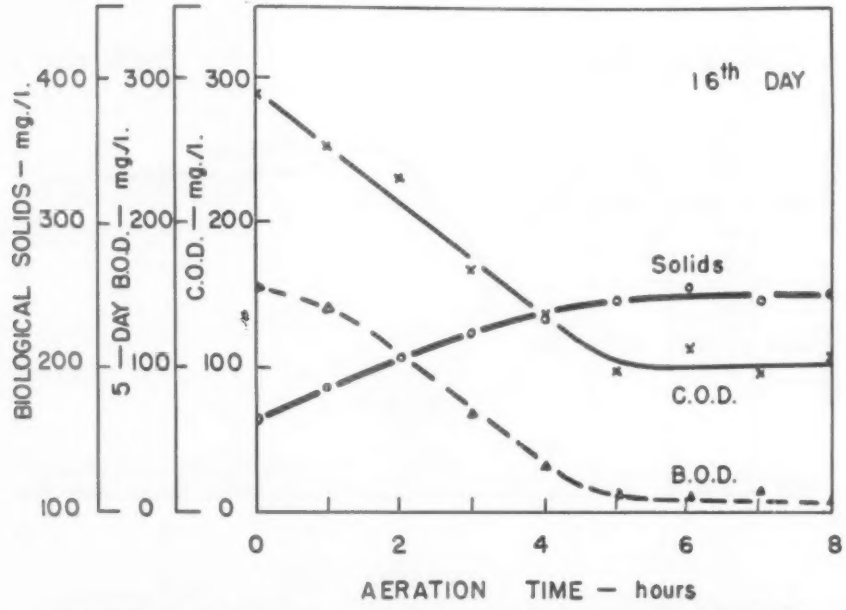

FIGURE 7.—Biochemical changes with aeration in an activated sludge unit fed 333 mg. per liter of arginine.

curred in the arginine culture on the 16th day following initiation. After an aeration period of 6 hr., the maximum solids concentration had been obtained and essentially all of the B.O.D. had been removed, whereas approximately 100 mg. per liter of C.O.D. remained. Although the data are not presented in Table II, 82 mg. per liter of C.O.D. remained in solution even after 23 hr. of aeration. The sludge mass in this culture was dense with a thin filamentous type organism present.

Activated sludge cultures were also developed on the following organic acids—formic, acetic, valeric, caproic, heptanoic, and benzoic. With the exception of formic acid, all of the cultures presented the usual biochemical changes in relation to time. The formic acid culture never became acclimated to the feed mixture during the 23 days of operation. At first there was a drop in pH in the culture to 4.8. Even after this was corrected, there was a definite toxicity present. Photomicrographs of the sludges developed on all the individual organic acids showed that the predominating organisms were morphologically different in each culture.

Table II shows the concentration of mixed liquor suspended solids and the amount of synthesis and B.O.D. removed for all of the activated sludge cultures after 23 hr. of aeration. With the exception of the cultures developed on methionine, all of the cultures showed at least 90 per cent B.O.D. removal on both the 16th and 23rd days. In the case of the methionine culture, 38 and 50 per cent of the B.O.D. were removed on the 16th and 23rd days, respectively, after an aeration period of 8 hr. Thus, although the rate of B.O.D. removal was increasing, there was some factor present which interfered with the rapid removal of methionine from solution.

Nitrogen Balances

Complete nitrogen analyses were made on each activated sludge system in order to establish a nitrogen balance as a check on the mass-organic matter balance. After the biological solids had been separated from the liquid phase by membrane filtration, the solids were dried and analyzed for total nitrogen. The filtrate was then analyzed for nitrites and nitrates, as well as for total nitrogen. In order to minimize the effect that nitrogen compounds adsorbed to the sludge might have, sludge was collected at the end of the aeration period (23 hr.) from each culture for analysis.

The nitrogen balances which were established for the various activated sludge cultures are shown in Table III. Since nitrite and nitrate nitrogen were not found, the balances have been set up using only the decrease in total nitrogen of the membrane filtrate and the nitrogen utilized in the formation of new biological solids. Regarding the nitrogen content of the biological solids, Porter (12) has pointed out that the total Kjeldahl nitrogen analysis does not quantitatively determine all forms of nitrogen, but gives results of only about 85 per cent of the total nitrogen present in the form of cellular protoplasm. Therefore, the total nitrogen values determined for the biological solids were adjusted on the basis of 85 per cent recovery.

It can be seen from Table III that, in the majority of the systems, the loss of nitrogen in the liquid phase exceeded that used for the synthesis of cellular material. The difference ranged from 0.7 to 12.0 mg. per liter. In those cultures where the amount of nitrogen used for synthesis exceeded the decrease of nitrogen in the liquid phase, the differences were all within experimental error.

Since the apparent loss of total nitrogen from the aeration systems was not a result of nitrification, two aeration studies were made using only the base inorganic salt solution to which 50 and 100 mg. per liter of ammonia nitrogen were added. Ammonia nitrogen determinations were made at vari-

TABLE III.—Nitrogen Balances of the Activated Sludge Cultures

Substrate	16th Day			23rd Day		
	Decrease in Total-N of Filtrate (mg./l.)	Increase in Total-N of Solids (mg./l.)	Difference (mg./l.)	Decrease in Total-N of Filtrate (mg./l.)	Increase in Total-N of Solids (mg./l.)	Difference (mg./l.)
Fructose	8.4	7.6	0.8	—	—	—
Galactose	9.6	8.9	0.7	—	—	—
Glucose	11.0	9.1	1.9	—	—	—
Lactose	—	—	—	13.5	8.8	5.0
Maltose	—	—	—	8.8	6.5	2.3
Mannose	11.0	9.2	1.8	—	—	—
Xylose	—	—	—	7.1	6.4	0.7
Alanine	15.3	3.2	12.1	14.4	5.3	9.1
Arginine	11.0	7.6	3.4	9.0	6.8	2.2
Glutamic Acid	12.5	6.0	6.5	12.9	7.1	5.8
Glycine	12.6	3.0	9.6	8.5	3.7	4.8
Leucine	17.6	17.8	+0.2	18.2	16.7	1.5
Methionine	11.1	6.5	4.6	9.3	5.0	4.3
Phenylalanine	21.8	11.8	10.0	15.2	10.3	4.9
Threonine	16.8	7.6	9.2	11.7	7.5	4.2
Tryptophane	13.3	9.4	3.9	11.9	9.8	2.1
Valine	19.7	12.2	7.5	18.2	11.8	6.4
Acetic Acid	8.8	8.1	0.9	9.0	7.5	1.5
Benzoic Acid	12.9	13.3	+0.4	17.6	12.0	5.6
Caproic Acid	18.1	13.8	4.3	14.8	15.1	+0.3
Heptanoic Acid	17.4	19.8	+2.4	19.2	16.6	2.6
Valeric Acid	13.7	12.0	1.7	17.3	11.6	5.7

ous intervals during a 24-hr. aeration period. The rate of aeration was approximately the same as that used for the activated sludge cultures. These data are shown in Table IV. During the 24-hr. period, a total of 15.1 mg. per liter of NH_3–N was lost from the solution containing an initial 50 mg. per liter of NH_3–N, while the 100 mg. per liter solution lost 14.8 mg. per liter of NH_3–N. From this study, it appeared that nitrogen could be stripped from solution by aeration and that the amount lost was independent of the NH_3–N concentration up to 100 mg. per liter.

TABLE IV.—Nitrogen Changes During Aeration of Inorganic Media Containing 50 and 100 mg. of NH_3–N per Liter

Time (hr.)	50 mg./l. NH_3–N			100 mg./l. NH_3–N		
	NH_3–N (mg./l.)	Loss (mg./l.)	pH	NH_3–N (mg./l.)	Loss (mg./l.)	pH
0	49.2	—	8.4	98.9	—	8.55
4	46.2	3.0	—	96.9	2.0	—
7	45.1	4.1	—	—	—	—
8	—	—	—	94.5	4.4	—
24	34.1	15.1	8.3	84.1	14.8	8.45

Discussion

The activated sludge process is operated on the basis of aerating the liquid waste in the presence of flocculated organisms, separating the flocculated organisms from the waste by sedimentation, and returning a portion of the settled organisms back to the aeration tank for seeding purposes. Thus, with prolonged operation, the organisms become acclimated to the waste material and, as a result, the most efficient organisms tend to predominate. The importance of acclimation is widely recognized at the present time.

In this study, activated sludge cultures were developed on different pure compounds using settled sewage as the source of seed. After an acclimation period of either 16 or 23 days, bio-

chemical analyses were made on the various cultures. Since it was believed that the biochemical changes taking place in each culture were related to the types and metabolic activities of the organisms present in the floc, photomicrographs were also taken of the different sludges.

Study of all the photomicrographs showed that the microscopic appearance of many of the sludges were similar, while others were quite different. In many of the cultures where similar sludges were observed, there was a structural relationship between the organic compounds upon which the cultures were developed. The biochemical changes which occurred in these cultures also showed a similar pattern. This was shown in the carbohydrate cultures where the hexose monosaccharides (glucose and fructose) and the hexose disaccharide (lactose) all had the same general appearance, *i.e.* small clumps of bacteria with large masses of a filamentous organism. Although the cultures developed on mannose and maltose are not reported here, they were also found to be similar both in their biochemical changes and morphological appearance. In this respect the pentose cultures (xylose and arabinose) were also similar as a group; however, the appearance of the sludges of these two cultures differed considerably from that of the hexose cultures.

Carbohydrates

Biochemically, the disaccharides are related to the monosaccharides in that both are metabolized by the same pathway after hydrolysis of the disaccharide to the monosaccharides. Thus, the organisms which were best able to metabolize the monosaccharides were found to be of the same type which were best able to utilize the disaccharides. Therefore, similar metabolism and similar organism predomination yielded sludges of similar appearances.

Like all biochemical phenomena, there was an exception to this condition. Sucrose is a disaccharide which hydrolyzes to yield two monosaccharides (glucose and fructose). However, the sludge fed sucrose did not have the same characteristics of the sludges developed on either glucose or fructose. Instead, the sludge was made up predominantly of bacteria which possessed a large amount of capsular material. Since sucrose is readily attacked by certain members of the genus *Leuconostoc* with the production of dextrans, a slimy polysaccharide, it is entirely possible that this was the predominating organism. Thus, the difference in appearance of the sludge was due to a different organism predomination which in turn was related to either a metabolic factor or the environmental conditions of the system.

Where the sludges had a different morphological appearance, it could usually be related to a difference in the chemical structure of the various compounds. In all probability the chemical structure of the compound being stabilized affects predomination as it affects the metabolic pathways of the organisms in the system. This was seen in the monosaccharides where both hexoses and pentoses were studied. The structural difference between the hexoses and pentoses lies in one less CH_2O group in the pentoses than in the hexoses. The one less carbon group in the pentoses causes them to follow a different metabolic pathway than the hexoses, and results in a predomination of an entirely different group of organisms. This same phenomenon was also apparent in the sludges developed on the fatty acids, where a difference of a CH_2 group accounted for a difference in predomination of organisms and resultant sludge appearance.

Most of the amino acid cultures showed similar biochemical changes. Appearances of the sludges were all different, some more so than others. This can be explained by considering the fact that the amino acids studied

were selected because of their structural difference.

Amino Acids

Of the amino acids studied, the biochemical changes which occurred in the arginine culture were of particular interest. From the data, it appeared that arginine was broken down with the valeric acid fraction being completely oxidized and the guanidine fraction being completely hydrolyzed. This can be shown by first considering the equation for the complete oxidation of arginine:

$$H_2N\text{–}C(NH)\text{–}NH\text{–}CH_2\text{–}CH_2\text{–}CH_2\text{–}CH(NH_2)\text{–}COOH + 5\tfrac{1}{2}O_2 \rightarrow 6CO_2 + H_2O + 4NH_3$$

According to this equation, the theoretical amount of oxygen required for the 333 mg. per liter of arginine in the feed would be 337 mg. per liter. This checked with the 342 mg. per liter which was actually determined. Therefore, the residual C.O.D. remaining after 8 hr. of aeration indicated that some fraction of the arginine molecule was not being biologically attacked or that this fraction was being metabolized at a slower rate. Although Figure 7 indicates data for only 8 hr., analyses were also made after 23 hr. of aeration. This data indicated a decrease in C.O.D. of 245 mg. per liter. Since the complete oxidation of the valeric acid fraction of arginine would theoretically require 225 mg. per liter of oxygen, it would appear that the nonutilizable fraction remaining from the metabolism by activated sludge was guanidine.

Speculation as to the metabolism leads to the conclusion that the microorganisms attacked the acid fraction of the arginine molecule and were stopped by the nitrogen atom in the straight-chain portion between carbons 5 and 6. This observation agrees with the work reported by Mills and Stack (7). They found that atoms other than carbon atoms in the chain of an organic molecule often interfered with aerobic biological oxidation.

Additional evidence of this was indicated in the methionine culture. In this culture, the C.O.D. remaining in solution after 23 hr. of aeration was 70 and 57 mg. per liter for the 16th and 23rd days, respectively. Considering this, along with the B.O.D. data in Table II and the fact that 38 per cent of the B.O.D. was removed on the 16th day while 50 per cent was removed on the 23rd day following 8 hr. of aeration, it is apparent that the culture was still undergoing acclimation. This may be related to the structural formula for methionine, which has a sulfur atom between the 4th and 5th carbon atoms.

The results presented in Table II are comparable to the biochemical data reported by both Ruchhoft *et al.* (2) on the removal of glucose, and Placak and Ruchhoft (3), who studied various pure compounds. In their studies, activated sludge cultures with approximately 2,000 mg. per liter of mixed liquor solids were used. The amount of organic matter fed each of their cultures was greater than the amount fed to the cultures reported in this study. Even though these differences existed, the per cent B.O.D. removal presented in Table II are similar to those found in the previous studies (2)(3). In considering the rate of B.O.D. removal, this study substantiates the conclusion drawn by Placak and Ruchhoft (3) that the rate of biochemical change was a function of the individual compound rather than the class to which the compound belonged. It was also interesting to note that all of their cultures developed on carbohydrates, with the exception of xylose, showed the presence of a filamentous organism which they identified as *Sphaerotilus natans*. The only carbohydrate culture in this study that did not agree with this observation was that developed on sucrose, which showed a sludge made up predominantly of capsulated bacteria.

Nitrogen

Regarding the loss of nitrogen during aeration, it appeared quite probable that the failure to obtain satisfactory nitrogen balances in the activated sludge systems was related to the stripping of nitrogen from solution by aeration. While it was true that aeration of the salt solution alone resulted in a loss of about 15 mg. per liter of NH_3–N and the activated sludge systems showed only a 1.0 to 7.0 mg. per liter loss, this apparent discrepancy could be attributed to certain physical and biochemical characteristics of the actively metabolizing sludges.

In considering the range of 1 to 7 mg. per liter of nitrogen lost in the cultures, mention should be made of the pH of these cultures. The pH of the carbohydrate and organic acid cultures ranged from 7.8 to 8.5 while the pH of the amino acid cultures varied from 8.3 to 8.65. These higher values in the case of the amino acid cultures were probably the result of deamination which caused the release of ammonia nitrogen. Because of the higher pH, more nitrogen appeared to be lost in the amino acid cultures during the aeration period than in the carbohydrate and organic acid cultures.

These results are somewhat in contrast to those reported by Heukelekian and Littman (13). Using activated sludge cultures, they found that their nitrogen balances, based on several analyses made over a 24-hr. aeration period, varied from − 1.6 to + 7.1 per cent of the initial total nitrogen value. However, in a recent study on the biological oxidation of amines, Mills and Stack (6) found in setting up nitrogen balances that the loss of nitrogen in their cultures was as high as 85 per cent. They presumed that this loss or release of nitrogen was as nitrogen gas.

Summary

The results of these laboratory studies, using acclimated activated sludge cultures developed on pure organic compounds, indicated the following:

1. Activated sludges developed on structurally related chemical compounds had similar morphological appearances and produced similar biochemical changes.

2. The chemical structure of the organic matter fed to activated sludge was found to be the controlling factor in predomination of microorganisms and in the biochemical changes when all environmental factors were constant.

3. The activated sludge culture developed on arginine indicated that there was a grouping in the chemical structure of the molecule which prevented it from being completely metabolized.

4. Activated sludges developed on chemical compounds which were structurally different were found to have sludges which were morphologically different. Because these cultures showed similar biochemical changes, the most efficient organisms predominated and these in turn were determined by the metabolic pathway through which the compound was attacked.

5. The loss of nitrogen during aeration of activated sludge cultures precluded the development of accurate nitrogen balances.

Acknowledgment

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MEN ON THE MOVE

Never before have men moved as much as today. A report from the McGraw-Hill Publishing Company states that over a 12-month period 565 out of every 1,000 key men in industry are on the move. A total of 343 new faces appear, 65 change titles, 157 shift, and 435 stay put.

Keeping track of men on the move is a big continuing job for any publication. We of SEWAGE AND INDUSTRIAL WASTES would be grateful if our readers would take just a minute to let us (and their Member Association secretaries) know whether or not the address which brought this issue is correct.

Particularly important at this time of year is for Member Association members to check and be certain they have notified their Member Association secretaries and the Federation office as to their correct title, employer, address, and spelling of name if any change has been made during the last year or two. The listings for the complete biennial directory of Member Association membership (March, 1958 issue of the Journal) close on December 31, 1957 for all paid-up members of record as of the year's end.

If you have made a move let us know. Many thanks.

Industrial Wastes

CHEMICAL-TYPE COKE PLANT SOLVES WASTE PROBLEMS BY COOPERATIVE EFFORTS*

By Philip S. Savage

Vice-President, Donner-Hanna Coke Corporation, Buffalo, N. Y.

In June, 1917, Donner-Union Coke Corporation was formed as a corporate partnership by the Buffalo Union Furnace Company which operated three small blast furnaces on the Buffalo River, and the Donner Steel Company which operated a small integrated steel plant with two blast furnaces, located approximately a mile further upstream. Both plants were then using Beehive Coke from Northern Pennsylvania to make iron in their furnaces.

World War I (1917) brought a great need for chemical products of coal, particularly for toluol which was urgently needed for the production of T.N.T., for benzol to make picric acid, and for ammonia which was needed for producing nitric acid and fertilizer. Congress authorized the Ordnance Department of the U. S. Army to build chemical-type coke plants where Beehive coke was being used, and to lease these to industry with options to buy the plants after the war was over.

The new Donner-Union Coke Corporation had acquired 54 acres of swampy land behind Donner Steel Company in Buffalo, which was leased to the Government, and in 1918 the construction of a 150-oven coke plant was started. The Koppers Company of Pittsburgh was given the contract, and the construction was under the joint direction of the Ordnance Department and the Donner-Union Coke Corporation engineers. The war was over before the plant was finished, but commitments were so great that it was decided to finish the plant and lease it to the coke corporation. Full title was acquired by purchase in 1935.

Shortly after the war, the Hanna Furnace Corporation of Cleveland purchased the Buffalo Union Furnace Company and its half interest in the coke corporation, and the name was changed to Donner-Hanna Coke Corporation. This name has remained until the present day despite the fact that Donner Steel Company became the Buffalo Plant of Republic Steel Corporation in 1929. The new coke plant was completed in 1920 and put into partial operation late that year.

The original plant consisted of 150 Koppers cross-regenerative vertical-flued ovens, carbonizing approximately 90,000 tons of coal per month. It has grown to a plant consisting of 252 ovens carbonizing 135,000 tons of coal per month, and producing monthly 93,000 tons of blast furnace coke, 1,350,000,000 cu. ft. of gas, 1,100,000 gal. of tar, 1,500 tons of sulfate of ammonia, 250,000 gal. of benzol, 50,000 gal. of toluol, and 20,000 gal. of xylol, as well as Coke Breeze, Buckwheat Coke, naphthalene, pyridine, and at the present time sodium phenolate.

Buffalo River

Donner-Hanna Coke Corporation at present uses approximately 10 m.g.d.

* Presented at the Spring Meeting, New York Sewage and Industrial Wastes Assn.; Lake Placid, N. Y.; June 17-18, 1957.

of water, which is returned to the Buffalo River from which it is originally pumped. Buffalo River is a small stream having violent fluctuations in flow. It is dredged from Lake Erie approximately six miles upstream and forms a basin containing 165,000,000 cu. ft. of water. The flow in this stream varies from a maximum of 27,000 c.f.s. to a summer minimum of approximately 20 c.f.s., and the average summer flow is less than 100 c.f.s.

The Buffalo River discharges into the Buffalo Harbor behind a breakwall at a point where the Niagara River, flowing at a mean of more than 200,000 c.f.s., is already formed and moving downstream at the rate of more than 1 m.p.h.

The banks of the dredged section of the Buffalo River are lined with flour mills, elevators, and various manufacturing plants, and at the upper end of the dredged section there are five large steel, chemical, and oil refinery plants including the Donner-Hanna Coke Corporation. These five plants discharge into the upper end of the Buffalo River a total of approximately 120 m.g.d. of water which they all pump from the river. It is important to note that in the summertime the water in the Buffalo River is used over and over by the industries along its banks. More than five times the flow is recycled before it reaches the Buffalo Harbor enroute to the Niagara.

In addition to the five heavy industries at the head of the river, other industries use Buffalo River water and return waste water to the stream. Prior to 1938 the City of Buffalo discharged sewage equivalent to a population of 244,000 people to the Buffalo River. There is still raw sewage going into the river equivalent to a population of more than 5,000 people. Today, at times of heavy rainfall, relief sewers carrying storm water as well as raw sewage discharge their overflow into the Buffalo River without treatment. The City of Buffalo and all the suburban areas, except perhaps the Town of Amherst, have combined storm and sanitary sewers, with the sewage treatment plants capable of handling only a reasonable increase in the normal flow.

The City of Buffalo is fortunate in having its water supply inlet located in the Emerald Channel where the strong flow to the Niagara River carries the pure deep water of Lake Erie to its intake. With this tremendous advantage, and a modern pumping and filtration plant, Buffalo has an excellent public water supply.

Early Conditions

When the Donner-Hanna Coke Corporation was built in 1919, care was taken to minimize pollution by the standards and methods that then prevailed. Settling sumps were installed to remove suspended solids. The acid sludge from the washing of light oil was treated to solidify the sludge and recover the spent acid. Oil intercepting sumps were installed to prevent oil from getting into the river if leaks should occur, and a small cooling tower was installed to keep the final cooler water containing small amounts of cyanide and phenol in a closed circuit.

In 1927 the increase of taste-producing wastes being discharged into Lake Erie and the Niagara River from various sources, combined with the installation of more effective chlorination facilities in the water treatment plants, created at times unpleasant tastes in the water supplies of the city and suburbs. While other compounds, some of which are natural, can cause these tastes, much of it came from phenol and related compounds. The New York State Board of Health and local health authorities took immediate action, and known plants that were discharging phenol into the waters used for drinking purposes were ordered to eliminate as nearly as possible this substance from their waste. Although it seemed to most people impossible that Buffalo River water could flow up-

stream to the Buffalo City intake, or to the Western New York Water Company intake, even under severe storm conditions, the Donner-Hanna Coke Corporation agreed to eliminate, as far as possible, phenol from its discharge.

Needing a quick method of completely eliminating phenol from the Buffalo River, and remembering that water wells drilled at the plant site had shown a strata of salt water 140 ft. below yard level, permission was secured from the New York State Department of Health to drill wells to this undrinkable black water, case them off from any fresh water sources, and discharge the ammonia still wastes that were contaminated with phenol into this salt water strata. A settling tank was quickly installed, together with sand filters to clarify the still waste, and the well drilled to the salt water strata. This well, and 9 others that were later drilled, completely absorbed the ammonia still waste for a number of years. However, about 1945 it became impossible, due to clogging of the rock pores, to continue to discharge the ammonia still waste in this manner. In the meantime, however, it had been quite conclusively shown that phenol in the Buffalo River was not the source of the chlorophenol taste in the City of Buffalo or Western New York Water Company water.

Following a report in 1946 by Dr. George E. Symons, consultant for the Buffalo Sewer Authority (1), conferences were held with the various industries on the Buffalo River and the interested government agencies. The report included waste studies of the plants on the Buffalo River, and offered conclusions and recommendations to control these wastes to a point that would be both practical for industry to do, and complete enough to protect the water supply of Buffalo and the communities downstream from Buffalo. A unique plan was suggested in the report that would make a reasonable cleanup of the Buffalo River possible, and at the same time allow heavy industry to continue to grow on this small stream. This plan consisted of improving on an idea adopted by the City of Milwaukee in 1902 whereby water was pumped from Lake Michigan to the upper end of the dredged area of the Milwaukee River and the Kinnickinnic River to prevent concentrations of pollution from building up in these rivers and being forced into Lake Michigan in large volume by flash floods and winds.

As early as 1937 G. E. Symons pointed out that fortunately Buffalo had five large users of water at the headwaters of the dredged area of the Buffalo River. This would make it possible for these five industries to use water pumped from Lake Erie, the discharge of which would increase the maximum flow of the Buffalo River more than five times, and thus prevent any build-up of pollution in the dredged portion of the river.

Donner-Hanna Coke Corporation in 1947, at a joint meeting of the interested public authorities, agreed to support the river water project, and at the same time agreed to install a dephenolizing plant of some type. It was suggested by the Buffalo Sewer Authority that pilot-plant studies be made of a biological filter plant for the benefit of all concerned, delaying choice of the dephenolizing method until these studies were completed. A biological pilot plant was designed and constructed in 1949 (Figure 1). Tests were run during the summer of 1949 and 1950 and the results looked fairly promising.

In 1950, the biological pilot plant was converted to a chlorine dioxide pilot plant. This required only minor changes, and 10 runs were made using chlorine dioxide as the destructive agent for phenol.

A review was made in 1953 of the results of both tests, and of the progress made in phenol recovery by the benzol absorption method. It was de-

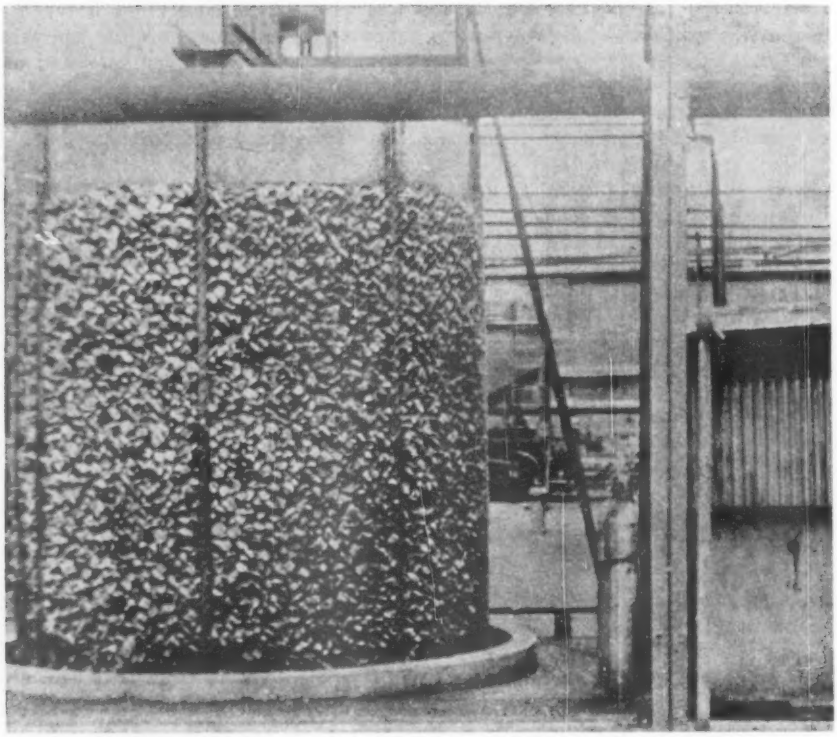

FIGURE 1.—Biological pilot plant to treat phenol wastes.

cided by the Donner-Hanna Coke Corporation that neither the biological filter method nor the chlorine dioxide method were suitable for the elimination of phenol in untreated still waste under conditions at Donner-Hanna, and the pilot-plant work was abandoned.

New York State Water Pollution Control Board

In 1949, the New York State Water Pollution Control Board was established. The tremendous task of putting the new stream pollution law into effect was promptly started. Hundreds of water pollution experts were called together, representing state, city and county health groups, the State Conservation Department, representatives of many communities throughout the state, and representatives of individual industries and industrial associations. These experts gave great help to the Control Board, and a workable program of water pollution control was established. This program required a classification of all waters of New York State as to their best use for all the people of the state. The waters of the state were to be classified from "AA," which was water so pure that it was perfectly clear and safe for drinking with simple chlorination, to "F" at the bottom of the scale. It was a practical program that would stop further water pollution in this fast-growing state, and improve much of the already polluted water.

The first Control Board hearings scheduled for Buffalo were held May 31 and June 1, 1951, and in 1953 the preliminary classification for Western New York waters was published, with

public hearings on these classifications held in Buffalo that same year. Final classifications for Western New York waters were announced in 1954. There followed conferences under the auspices of the Control Board, and participated in by representatives of local health boards, the U. S. Public Health Service where boundary waters were involved, and both individual industries and groups of industries. Plans were made to cooperatively study individual waste problems of both industries and communities. Finally standards were set and agreed upon by the industries and communities whose waste problems had been studied.

In the case of the Donner-Hanna Coke Corporation, a number of meetings were held with representatives of the Control Board and the state and local health authorities. Pollution sources from various sections of the plant were studied, and a plan was agreed upon which would carry out the pollution control program mandate. This plan, combined with the efforts of the City of Buffalo and of the other industries on the Buffalo River, would bring this stream to its assigned classification.

Abatement Plans

The pollution abatement plans of the Donner-Hanna Coke Corporation, agreed to in June, 1955, were:

1. The company should prepare plans for methods and necessary facilities to control and provide maximum practicable reduction of the phenolic wastes. These plans should be submitted to the Water Pollution Control Board for approval. The necessary units should then be constructed and operated in a satisfactory manner.

2. A thorough study should be made of all the piping at the plant to see that all the wastes containing phenol, cyanide and/or oil, are effectively treated before discharge to the process sewer. This would include a careful check of the gas final-cooler water closed system to see that there was no overflow to Buffalo River.

3. The company should participate with the other major industries on the Buffalo River in furthering consideration of the Buffalo River Pollution Abatement Project-Water System.

4. Arrangements should be made to collect all the sanitary wastes and discharge them to the municipal sewers or, in the case of isolated small toilets, to approved septic tanks.

5. A continuing cooperative study of the receiving stream and plant effluents should be conducted by the industry and control agencies. These studies should include bio-assays, the purpose of which would be to determine whether or not the effluents contained toxic or other substances that would be inimical to fish life or affect public water supplies drawn from Lake Erie or the Niagara River. Work should then be undertaken on any additional treatment measures indicated to be necessary to meet the classifications of the Buffalo and Niagara rivers and Lake Erie.

6. If the Buffalo River Pollution Abatement Project-Water System was not constructed, a reappraisal of the requirements for further waste treatment would be necessary.

7. The company should work out with the Water Pollution Control Board arrangements for effluent sampling, maintenance of operating records, and periodic reports to the Water Pollution Control Board.

Item No. 2 had already been completed by the installation of a new and enlarged cooling tower which would keep the final-cooler water containing small amounts of cyanide and phenol in a completely closed circuit.

Item No. 4 covering the disposal of sanitary sewage was already complete except for installation of small outlying septic tanks.

Items Nos. 5, 6 and 7 were already completed and ready to be put into

operation when the new dephenolizer was built and put in operation.

Item No. 3 has already been discussed, and Donner-Hanna had agreed in 1947 to cooperate with other industries in bringing this into being. This plan is now well under way, and legislation enabling the City of Buffalo to build a pumping plant and lease it to industry has been passed.

Item No. 1 was of major concern to the company. Preliminary work had already been completed, and a benzol extraction-type dephenolizing plant at a cost of approximately $250,000 had been decided upon by the company and was quickly approved by the New York State Water Pollution Control Board. In October, 1955, a contract was let for the construction of such a plant. This process is not a new one, and a reasonably successful plant of this type had been in operation at Troy, N. Y., since about 1925. Several manufacturers now build this type of plant, with variations only in design of the liquor oil contact equipment. The Koppers-Loe process provided contact towers that seemed to offer the greatest efficiency with a minimum of maintenance.

Koppers-Loe Process

Operation of the Koppers-Loe process consists of the following steps:

1. The phenol-bearing, crude ammonia liquor, after filtering and cooling, passes through two specially designed highly efficient contact towers in series. Light oil is pumped countercurrently to the liquor in the contactors, where, due to the intimate mixing, the phenol is extracted from the liquor by the light oil.

2. The dephenolized liquor flows by gravity to storage tanks and thereafter to the ammonia stills as feed. After distillation of the ammonia from the feed, the bottoms are sufficiently low in phenol concentration to be discharged to the inland waters.

3. The phenolized light oil from the contact tower is pumped to the top compartment of a three-section tower. Here any traces of ammonia liquor entrained with the oil are removed by decantation.

4. The decanted light oil flows by gravity through the lower two sections of this same tower. These sections comprise a multiple contactor for phenolized light oil and caustic soda solution in which the phenol content of the light oil is reacted upon by the caustic soda to form sodium phenolate. The light oil flow is upwards through each of the two sections, beginning with the bottom one. At the outlet of the top section, it is sufficiently dephenolized to return to the light oil circulating tank from which it is pumped to the liquor contact towers to begin the next phenol absorption cycle.

5. Caustic soda solution is pumped in batches to the two lower sections of the three-section tower. Step No. 4 indicates that the phenolized light oil passes upwards through these two batches of caustic in series and that the reaction produces sodium phenolate. When the conversion of the lowermost batch of caustic has reached about 70 per cent, the resultant phenolate solution is transferred to a springing plant to make crude concentrated tar-acids or to a concentrator where the excess water and light oil are boiled off before storing as phenolate. At Donner-Hanna the conversion of caustic to tar acids is not less than 85 per cent at the efficiencies being accomplished. In the meantime, the caustic soda from the middle compartment is dropped to the bottom one, and that from the top compartment is dropped to the middle compartment. A fresh batch of caustic soda solution is pumped into the uppermost of the three contact compartments from the caustic soda dilution tank and the cycle is resumed.

The towers for contacting the ammonia liquor and light oil are specially designed units containing multiple trays

TABLE I.—Typical Operating Results, Koppers Light Oil Extraction Dephenolizer Donner-Hanna Coke Corporation

Date (1957)	Liquid Treated (gal./day)	Phenol Content (p.p.m.)		Phenol Removed (lb./day)	Removal (%)
		Crude Liquid	Treated Liquid		
Apr. 22	66,000	1,531	23	829	98.5
23	73,000	1,589	21	943	97.6
24	82,000	1,813	22	1,223	98.8
25	96,000	1,988	19	1,575	99.0
26	99,000	1,804	23	1,469	98.7
Feb. avg.	87,000	1,923	22	1,369	98.9
Mar. avg.	89,000	1,760	18	1,288	98.9
Apr. avg.	89,000	1,693	24	1,235	98.6

through which the streams of liquor and light oil flow countercurrently and gently. The special design serves to mix thoroughly the light oil and liquor on each tray. Since there are no moving parts and no precipitates in these towers, a regular maintenance expense is not anticipated.

The Koppers-Loe process is believed to be the best so far offered to the coal chemical industry for removal and recovery of phenol from crude ammonia liquor and simultaneous reduction of the phenol in the waste from the ammonia stills.

The dephenolizing plant was put in operation in late December, 1956, and from the start gave efficiencies beyond expectations. Table I presents typical operating data for the dephenolizer.

The small amount of phenol remaining in the coke plant effluent discharged to the Buffalo River is insignificant in the normal flow of the river. For all practical purposes it is oxidized completely before dilution with the 200,000 c.f.s. flow of the Niagara. It is believed that no phenol from the Donner-Hanna works can now reach any water supply in Lake Erie or the Niagara River.

The Donner-Hanna Water Pollution Abatement Plan established by the New York State Water Pollution Control Board will be completed this year. Vigilance must be maintained in inspection and operation to make certain that carelessness does not nullify the plans so carefully drawn up and carried out at considerable expense.

Conclusion

The cooperative attitude of industries, communities, and governmental agencies in working together for the best interests of all the people is resulting in a concerted effort to abate and control pollution in the Buffalo and Niagara rivers. Health and happiness might be achieved in a wilderness without pollution of any kind, but it is doubtful that prosperity as the people of this country want it would be found there. Therefore, the enforcement of air and water pollution control laws must be a compromise between the ideal and the practical.

Acknowledgment

The helpful cooperation of the Donner-Hanna Coke Corporation staff and the many others in government agencies, municipalities, and industries who have had a part in this pollution control activity is sincerely appreciated.

Reference

1. Symons, G. E., "Buffalo River Stream Pollution Studies." Buffalo Sewer Authority, Buffalo, N. Y. (1946).

MODERN APPROACHES TO PULP AND PAPER MILL WASTE PROBLEMS *

By Harry W. Gehm

Technical Advisor, National Council for Stream Improvement, Inc.

It is increasingly obvious that the old standbys of sewage treatment—the clarifier, the trickling filter, and the activated sludge process—are not the answer to all organic waste problems. Indeed, waste treatment as such will not ultimately provide the whole answer to all the surface water quality problems. Admittedly, the present methods of sewage treatment, when intelligently applied to industrial effluent treatment problems, can and are finding a greatly increased application. Research and development work of the past 10 years have improved the efficiency of the standard techniques and broadened their application to industrial wastes. In some instances such application has also pointed out not only the limitation of specific treatment methods, but on relatively small and congested watersheds it has shown that treatment alone will not ultimately suffice. These limitations are clearly apparent in the data presented by the ORSANCO Chemical Industry Advisory Committee report on "Current Practices in Municipal Treatment of Industrial Wastes."

Suspended Solids Removal

Examples of the limitation of suspended solids removal techniques used for sewage clarification which fail in pulp and paper waste treatment, are as follows:

1. Failure of sedimentation devices to perform under rapid changes of temperature, flow, and waste characteristics.

2. Failure of such devices to provide an adequate degree of sludge thickening or produce a relatively uniform degree of thickening so that a movable and sufficiently dense slurry can be continuously produced. This is often not due to a failure of the equipment, but rather a demand upon it which it cannot be expected to meet because of feed characteristics and flow variations. For a number of reasons the obvious answers—equalization or recirculation of sludge or effluent, are not as easily applied as may first appear.

3. Entirely satisfactory devices for removing entrained air from clarifier influents are not yet available.

4. Where chemical treatment is applied, the presence of dissolved organic matter from pulping liquors or wash waters can render coagulants useless or cause high sludge hydration. In other cases, constantly varying concentrations of organic matter can change the coagulant demand so rapidly that the correct dosage range cannot be applied as necessary.

5. The use of dispersing agents and colloidal pigments, antifroth agents, and some sizing materials upset coagulation techniques completely or render effluents highly turbid when only traces of the material are present.

A good example of colloidal pigments is titanium dioxide. One part per million of this pigment is equivalent in turbidity to 20 p.p.m. of the dispersed silica as used in the preparation of the "Standard Methods" tur-

* Presented at 1957 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Chicago, Ill.; June 26–28, 1957.

bidity standards. Therefore, what would be considered an excellent and good appearing effluent from the standpoint of the chemical coagulation of sewage (20 p.p.m. of suspended solids), would not have a good appearance if produced by coagulation and clarification of an effluent from a paper mill using titanium dioxide. Here, if the weight of suspended solids in the effluent was similar, the turbidity would be 400 p.p.m. and its appearance very poor, particularly because of the brightness of the pigment.

Sewage sludge thickens generally to a consistency that can be handled by devices capable of further concentrating the material for disposal by drying or incineration. Many papermaking operations produce effluents containing settleable solids which settle and compact to very low consistencies (as low as 0.5 per cent solids). These defy even the best methods of concentration, limited only to laboratory use.

For these reasons, techniques other than sedimentation have been explored and, in many cases, applied to handling difficult clarification and thickening problems in the pulp and paper industry, as well as in others. Flotation and direct filtration methods have broadened the scope of clarification to cover a greater number of effluents. Typical examples of these devices are shown in Figures 1 and 2. The liquid

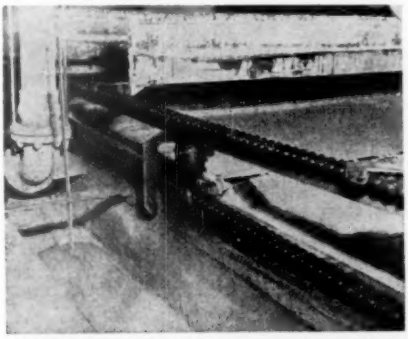

FIGURE 1.—Flotation save-all treating pulp and paper mill wastes.

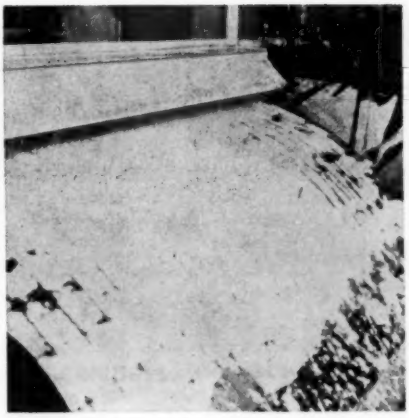

FIGURE 2.—Vacuum filter operating on paper mill wastes.

cyclone and super centrifuge now under intensive study, promise to add further to the number of effluents which can be successfully clarified.

It might be apropos to comment on what the term "successfully handled" means in terms of equipment performance. To those unacquainted with mechanical processes, it can and often does mean top efficiency performance 100 per cent of the time. To those close to such operations, such performance is obviously unobtainable and the expectancy of such is not sensible. However, the customer for stream pollution control, *i.e.*, the public, often expects this degree of efficiency and performance to be obtainable. Somehow there is a greater expectancy for this attainment in respect to industrial effluent than from municipal sewage treatment plants. It is a well-known fact that a good piece of equipment in the municipal waste field is one that operates 90 per cent of the time. It will operate at peak efficiency only 70 per cent of the time over the period of a year, even under ideal conditions.

To meet continuous, highly efficient waste treatment performance requirements in the pulp and paper industry, attempts have been made to use secondary and even tertiary clarification

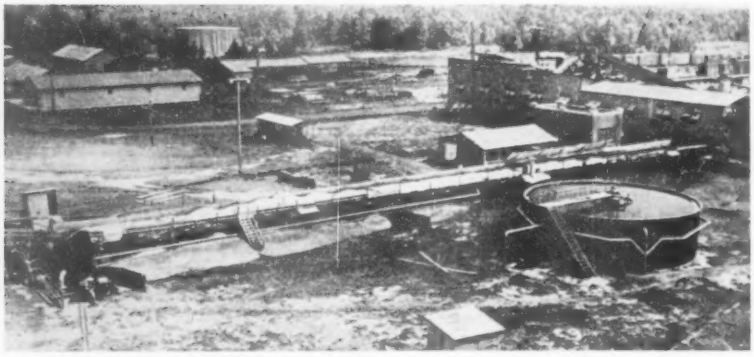

FIGURE 3.—Activated sludge plant.

devices. These units have consisted of clarifiers preceding and following filtration devices and the use of more or less catch-all sedimentation basins or lagoons prior to final effluent discharge. One such device which has in recent years come into rather wide use in the South consists of a circular earth embanked basin, equipped with a sludge collector mechanism. These basins are built in diameters up to 250 ft. to handle entire mill effluent flows of from 15 to 35 m.g.d.; the effluents usually have been preclarified by vacuum filtration within the mill. Under extreme conditions, these installations are accompanied by manually cleaned diversion basins for use during their down time. Such arrangements have reduced the cost of secondary clarification to a reasonable level for large mills where land disposal of the resultant sludge is feasible. It can readily be seen that such practice permits better use of disposal areas and improves clarification over ordinary lagoons or manually cleaned basins.

B.O.D. Reduction

In the field of oxygen demand reduction, biological sewage treatment methods have proven useful and efficient in some instances. In other cases, they are obviously not applicable or hopelessly inefficient when economics are considered. Sometimes biological treatment fails, due to the fact that residual factors such as color or turbidity remain in the effluent despite good B.O.D. reductions. Thus the application needs to be broadened, the efficiency improved, or other than biological methods used to do particular jobs. As far as the application of sewage treatment techniques to pulp and paper mill effluents are concerned, much progress has been made but results to date indicate that there is still considerable work to be done.

Trickling Filters

The trickling filter has not yet proven itself to be an effective or highly efficient device for handling mill effluents. Even the use of expedients such as two-stage filters, plastic filter media, temperature control, forced ventilation, recirculation, and nutrient addition have not raised loadings to an attractive level and, in many instances, consistently high B.O.D. removals cannot be obtained.

Activated Sludge

Of much greater promise has been the activated sludge process and its modifications. This was first tested and applied to kraft mill effluents. Two large scale installations have been made: one at Covington, Va., and the other (Figure 3) at Lufkin, Texas. These have been successful to a degree

and have served to point out some of the difficulties arising largely through mill process changes, production variations, and new additives, as well as basic limitations. The process produced little or no color reduction and may even darken the color of the waste, rendering the receiving stream less attractive in appearance than if the effluent were discharged untreated.

Excess sludge disposal, in some instances, remains a serious problem when some wastes are treated. For very strong effluents, fermentation processes such as the production of high protein feed supplements, represent more rational biological handling than do treatment processes.

On the encouraging side is the fact that much higher efficiencies in terms of detention requirements have been obtained for a number of effluents than are commonly achieved in sewage treatment practice. These are due to employment of nutrients, the discovery that the process is highly efficient at high temperatures (up to 55° C.), the use of high sludge concentrations and, in some cases, the application of contact stabilization. The fact that the sludge is fed at a continuously high rate may account for some of the efficiencies obtained and the absence of bulking troubles.

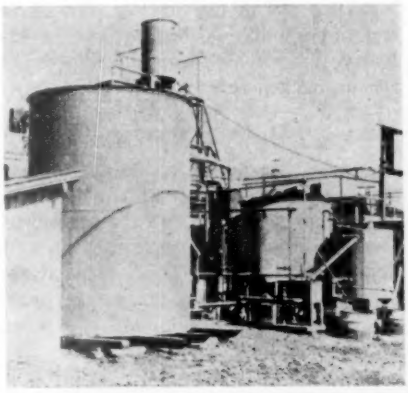

FIGURE 4.—Activated sludge pilot plant, New York and Pennsylvania Co., Johnsonburg, Pa.

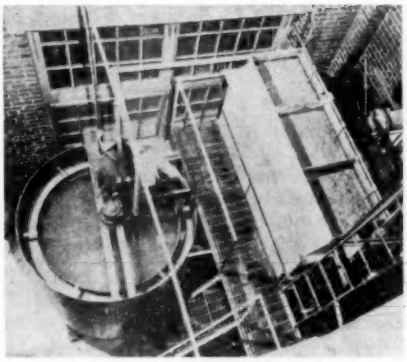

FIGURE 5.—An activated sludge pilot plant for the Mead Corp.

Other factors which broaden the application of activated sludge process is the ability of activated sludges produced from some wastes to not only survive in good condition, but remain highly active during wide pH changes and strength variations in the feed. Turbo-aeration devices have permitted treatment of wastes with B.O.D. values of several thousand parts per million. Sludge destruction by autogenous respiration holds promise of alleviating the excess sludge problem. At present, 12 pilot plants are in operation, testing this process on various types of pulping and papermaking effluents. Two of the units are shown in Figures 4 and 5. Typical results from some of these test units are given in Table I.

Stabilization Ponds

The stabilization pond has been the most widely employed means for reducing B.O.D. in the industry. There are 12 such installations in operation at large kraft mills in the South and they have proven effective. Recently, Ratliff (1) reported on the effectiveness of a pump recirculated basin for treating paperboard mill effluent. Another such installation is being tested at a rag and flax paper mill, and a third at an integrated mill. The latter

TABLE I.—Summary of Results, Pulp and Paper Mill Pilot Aeration Plants

Waste	Aeration Tank Details			Aerator Susp. Solids (p.p.m.)	5-Day B.O.D.	
	Capacity (gal.)	Aeration Period (hr.)	Daily Volume (gal.)		Load (lb./1,000 cu. ft./day)	Reduction (%)
Kraft, total effluent	12,600	3–6	40,000–80,000	1,500–2,500	100	90
Soda, diluted black liquor	1,230	4.2	4,300	1,900	115	92
Sulfite, soda, old paper	3,750	2–6	12,300–33,000	3,000	95	80–93
Neutral sulfite machine water	1,230	4–5	5,700	1,500	72–150	60–83
Neutral sulfite, machine water, news and chip	317,000	6–9	750,000	1,500–2,000	45–58	75–90
De-inking	92,300	4	460,000	6,800	75	73
Coated paper, broke wash	1,230	6	2,700	6,900	68	97
Boardmill, settled white water	8,500	4	38,000	2,000–3,000	66	80–90
Domestic sewage	—	4–6	—	1,000–2,500	30–60	95

two employ air diffusion to obtain circulation and aeration. Effective use of successive oxidation basins, with turbulent flow between them, for treating kraft effluent has been reported by Webster (2).

It appears from the results obtained to date that much improvement in oxidation basins is obtainable, that their application will be broadened, and their use in combination with small mechanical biological treatment units may prove attractive. In any event, one of the best features of such basins is that they come much closer to continuous high efficiency performance than any mechanical device.

Land disposal and irrigation use cannot pass unnoticed. The intelligent use of the microbiology of the soil for oxidizing organic wastes has been employed only recently. Previously, little attention was paid to organic loadings in respect to land disposal. Adherence to the allowable loading is now recognized as the factor which makes this technique successfully operable. However, the low loading requirement also limits its application, particularly in the pulp and paper industry, because of the large land area required per unit of organic matter oxidized in a given time. In addition, volumetric loading imposes another limitation.

Effluent Utilization

The use of kraft pulp mill effluents, as well as papermaking effluents, for irrigation has been successfully practiced in arid regions of this country. Both vegetable and fodder crops appear to thrive under such practice and no soil damage has been detected to date. Two factors appear to delay wider use of kraft mill effluent for irrigation. One is consumer acceptance and the other is the great area over which distribution would be required to dispose of the effluent volume from these mills which ranges from 15 to 35 m.g.d. Theoretically attractive to the industry is the use of the effluent to irrigate woodlands, but to date no effective means has been developed for accomplishing this economically.

Other Processes

Organic wastes which do not appear amenable to sewage treatment methods, or adoptions of them, are the subject of a considerable amount of research and development work. Chemical, heat recovery, drying, and incineration processes have been worked out for some wastes and are now in operation. Examples of this practice in the pulp and paper industry are the magnesium and ammonium base sulfite liquor recovery processes.

The Mead Corporation and the Institute of Paper Chemistry processes for neutral sulfite semi-chemical spent liquors are now being tested in full-scale units. The development of the kraft recovery process to an extremely high degree of efficiency must not be overlooked. Another is the extensive work on the Zimmerman wet combustion process as applied to pulping and other wastes of high organic concentration. Research on hydrolysis of a number of wastes has been conducted by the National Council for Stream Improvement and others. Catalytic oxidation of solvent containing effluents was explored by the du Pont Company.

Development of a color removal process from pulping and bleaching effluents by chemical methods, which could be integrated with the standard kraft mill recovery system, has been the subject of almost 10 years research by the pulp and paper industry. Although repeated bottlenecks have appeared in this development, and it is not yet ready for application, progress continues toward solving the problems encountered. A pilot plant which played a large part in these studies is shown in Figure 6. Hence, through many different approaches solutions to the multitude of effluent problems besetting the pulp and paper industry will appear in time.

Available Dilution

One factor which has not often been stressed enough is that of effluent control in respect to the available volume of dilution water. Pollution is largely a summer or low runoff disease and should be treated as such if communities and industries along watersheds and estuarial areas are to continue to expand. The holding or regulated discharge lagoon, the tidal basin, and the river impoundment have all been employed to advantage for the purpose of maintaining a more uniform dilution of effluents the year round, thus preventing critical periods of stream pollution.

It appears that present thinking must expand in this direction, notwithstanding considerable opposition. It is a simple fact that rivers must be used to drain areas of high population density except in some cases near the mouth of streams where large interceptor sewers and ocean or large lake discharges are practical. It is obvious, from the rapid growth of large cities,

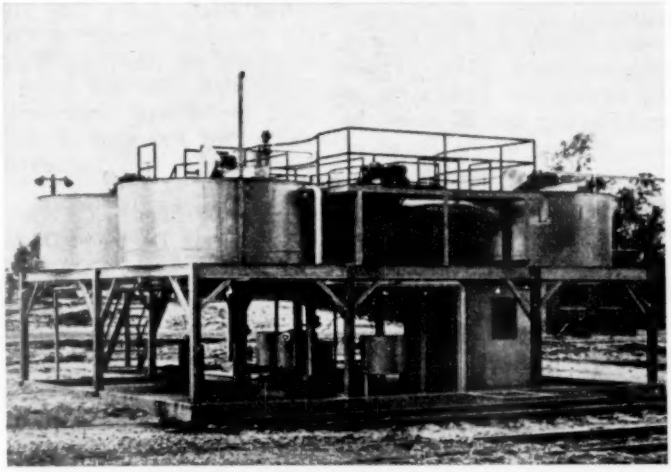

FIGURE 6.—Color removal pilot plant.

that attempts to spread out the population and industry have been successful only to a limited degree.

In quite a number of areas the point is being approached where sufficient dilution water is not available to prevent serious pollution, despite a high degree of treatment of all sewage and industrial effluents. Will these areas then stagnate or will means be taken to utilize better the total annual flow of the stream for drainage purposes? Possible impoundments must be studied from the standpoint of flow regulation alone, and any other benefits derived, such as power production, must be considered secondarily. The use of flood flows for carrying off impounded wastes, both liquid and semi-solid, must be thoroughly evaluated.

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1. Ratliff, F. C., "The Use of a Circulating Lagoon in a Paper Mill Effluent Program." 12th Indus. Waste Conf., Purdue Univ. (1957).
2. Webster, W. T., "How National's Nature Ponds Work." *Pulp and Paper*, **30**, 4, 114 (1956).

HOWARD E. (TED) MOSES DIES

Howard E. (Ted) Moses, first Secretary-Treasurer of the Federation, died at Reading, Pa., on November 13, 1957. He had recently suffered a heart attack. Ted Moses served as Secretary-Treasurer to the Federation when it was originally organized in 1929, until 1941 when it was reorganized with a treasurer and a part-time executive secretary. His untiring efforts in this position contributed greatly to the growth of the infant Federation. The Federation honored him with Honorary Membership (1943), the Kenneth Allen Award (1945), and the Charles Alvin Emerson Award (1951). In addition to serving the Federation as Secretary-Treasurer for 13 years, he also was a director to the Board of Control.

H. E. Moses was born on October 15, 1875 in Muhlenberg, Pa., and received his education at Dickinson College, University of Maryland, and The Johns Hopkins University. In 1908 he joined the Pennsylvania State Department of Health. He served the department in various positions of increasing responsibility, and in 1942 he was appointed Director of the Bureau of Sanitary Engineering, the position he held at the time of his death.

He participated in the organization of the Ohio River Valley Water Sanitation Commission and served as Chairman. Always active in stream sanitation work, he also served the Interstate Commission on the Delaware River Basin, the Interstate Commission on the Potomac River Basin, the Great Lakes-Upper Mississippi River Board of Engineers and the Conference of State Sanitary Engineers.

Ted Moses was a Life Member of the American Society of Civil Engineers and the American Water Works Association. He was active in many local professional organizations, and was a Past President of the Pennsylvania Sewage and Industrial Wastes Association.

In 1953 Dickinson College conferred the Honorary Degree of Doctor of Science on him.

Those who had the privilege of knowing Ted Moses will always remember his efforts as a pioneer for clean streams and his accomplishments in the sanitary engineering field; his service to the Federation will be long remembered.

INDUSTRIAL WASTES EFFECTS AT THE SOUTH SAN FRANCISCO, CALIFORNIA, SEWAGE TREATMENT PLANT*

By Henry L. Schweining

Superintendent of Sanitation, South San Francisco, Calif.

The South San Francisco-San Bruno sewage treatment plant was constructed at a cost of $1,000,000 exclusive of the 15-acre site. When the plant was put in operation in February, 1952, the combined population of the two cities was 30,000. Today the population is 60,000.

The designed capacity is 8 m.g.d. with a peak of 13 m.g.d. The domestic and industrial wastes can be kept separate or treated together, because all of the equipment is in duplicate.

There are two influent channels each with a remote recording flow meter and a recording pH meter (range of 2.0–12.0). When the pH meter registers a reading above or below the required plant operating pH range of 5.5–10.5, an investigation is undertaken to locate the source of the high or low pH waste. In most cases it is located.

The pretreatment units consist of automatic bar screens, two grit chambers with straightline grit collectors and a screw conveyor to the grit hoppers. The grit chambers are aerated and only a limited amount of air is used, as an excess carries sand into the flocculation tanks. The original wearing shoes on the grit buckets wore out in six months. Some experimenting was done with rubber riveted to the shoes. As the rubber did not show excessive wear after several months, each wearing shoe was vulcanized with a piece of rubber 4 in. by 4 in. by ½ in. thick. These rubber-soled shoes have been in continuous operation for four years and do not show any appreciable amount of wear.

There are four flocculation tanks and four primary sedimentation tanks. Air is furnished by two blowers. The sedimentation tanks are equipped with sludge collectors and pipe skimmers. Raw sludge is drawn by gravity to either of two sludge thickening wells and pumped to the digesters.

There are two 70-ft. primary digesters equipped with floating covers and heated by two sludge heaters. The No. 2 digester has a gas recirculating system, which was installed by the plant personnel about 18 months ago, and has eliminated the scum problem in that digester. The secondary digester is also 70 ft. in diameter with a floating cover that serves as a 20,000-cu. ft. gas holder.

The plant personnel constructed an incinerator in which all screenings from the bar screens are burned. This amounts to about 2 cu. yd. per day.

Both domestic and industrial wastes are pumped into the sewage treatment plant. The domestic waste pumping station has a capacity of 10,600 g.p.m. and pumps to an equalizing tank at the treatment plant. There are five industrial pumping stations and two more under construction.

Present average flow is 6 m.g.d. with peaks of 10 m.g.d. Flow is equally divided between domestic and industrial wastes. The strongest industrial wastes come from three meat processing plants

*Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

and a packing house, a tannery (chrome process), a steel pickling plant, and a shop towel laundry service.

Table I presents a summary of the treatment plant operating data for 1956.

Packing House Wastes

The Swift and Company slaughter house, one of the largest meat packing plants on the Pacific Coast, has been discharging untreated wastes into San Francisco Bay for many years. With the completion of the industrial sewer system in 1955, Swift and Company installed pretreatment and began discharging to the sewers in February, 1957. Their average daily weekday flow is 700,000 gal.

Pretreatment consists of a large basin with skimmers for the removal of grease and settling of miscellaneous solids. Paunch manure and solids from the bottom of the basins are removed by two vibrating liquid type screens which are 4 ft. by 8 ft. in size and use 20- by 30-mesh screening. The screened paunch manure is delivered to the sewage treatment plant by truck and dumped on the sludge drying beds. It is spread to about 6 in. in depth and used as a filter base upon which the digested sludge is spread. After spreading the paunch manure, the beds are flooded with sludge containing 10 to 12 per cent solids, then allowed to dry from 14 to 30 days. At about 60 per cent moisture content the sludge and filter base are roto-tilled by the Geraghty process. The flooding and tilling procedure is repeated three to four times, then the tilled sludge is harvested.

In the near future Swift and Company will connect to the system the wastes from the wool pullery after pretreatment equipment has been installed. Pretreatment is required because there is a large amount of sulfides in their process. The flow will add another 300,000 g.p.d., making a total of 1 m.g.d. from this one industry. The pH of the spent sulfide solution from the wool house will be adjusted to the required range of 5.5 to 10.5 and will be treated to remove dissolved sulfides. The treated wastes will contain elemental sulfur.

Swift and Company pays a sewer rental charge of $25,000 per year based on the volume of wastes water discharged to the sewer system.

TABLE I.—Summary of Operating Data for 1956, South San Francisco Sewage Treatment Plant

Item	Avg.
Flow (m.g.d.)	6
Grit (cu.ft./m.g.)	13
Suspended solids:	
Influent (p.p.m.)	497
Effluent (p.p.m.)	220
Reduction (%)	58
B.O.D.:	
Influent (p.p.m.)	600
Effluent (p.p.m.)	278
Reduction (%)	54
Settleable solids (ml./l.):	
Influent (p.p.m.)	21
Effluent (p.p.m.)	4
Reduction (%)	80
Total solids:	
Influent (p.p.m.)	1,884
Effluent (p.p.m.)	1,327
Reduction (%)	30
Digesters, primary:	
Volatile acids (p.p.m.)	5,000–6,000
Alkalinity (p.p.m.)	11
Dried sludge per day (ton)	2.6
Gas production per day (cu.ft.)	92,200

Tannery Wastes

The Poetsch and Peterson Tannery produces soft, light weight leathers by the chrome process; in addition, a small amount of vegetable tan is used. The wastes consist of hide soak and wash waters, lime soak and wash waters, sulfite de-hairing wastes, spent chrome salts, and vegetable tannins. The daily waste flow contains 33 cu. ft. of hair.

Pretreatment consists of a rotating quarter-mesh screen to remove hair and fleshing. A settling basin with no

method of mechanical sludge removal is also used. The chrome wastes are by-passed to a storm sewer as chromium will inhibit sludge digestion. The treatment plant receives all wastes except the hair and chrome wastes.

Plans for a pretreatment plant for the treatment of chrome wastes and removal of excess suspended solids has been authorized by the tannery. This plant will eliminate a sewer surcharge of $9.00 per 1,000 lb. of solids (dry weight) which amounts to $4,275 plus the waste water volume charge of $2,300.

Laundry Wastes

Shop Towel Service Laundry provides wiping cloths for industrial use. The wastes have a high B.O.D., grease, and suspended solids content as compared to that of ordinary laundries and it is the principal source of oils at the sewage treatment plant. The suspended solids including the grease are as high as 5,000 p.p.m. Only 500 p.p.m. of suspended solids may be discharged without paying a sewer surcharge. Therefore, the laundry pays a rather high surcharge.

All floating materials and grease received at the sewage treatment plant are removed by manually operated pipe skimmers to sludge thickening wells where they are refloated. The sewage is pumped to the head of the plant and the floating materials are pumped to the digesters.

The laundry has recently installed a settling basin with baffles and this removes a large percentage of settleable solids and a small amount of oils and grease. Most of the oils are dispersed as the temperature of the tank contents is 160° to 180° F. After installing the settling basin there has not been any sewer stoppage in the main sewer lines. The laundry pays a surcharge of $4,378 on excess suspended solids and $3,111 on the volume wastes charge.

Pickling Wastes

The pickling wastes of the Colorado Fuel and Iron Company come from a process to remove iron oxides (mill scale) before cold drawing and other finishing operations are performed. The steel is immersed in a hot sulfuric acid bath for several hours and washed with water. Iron is dissolved in the acid-forming ferrous sulfate and the strength of the acid is reduced. Additional acid is used, increasing the ferrous sulfate content and further reducing the acid activity. The spent pickling liquor eventually must be discarded. This waste contains about 1 per cent by weight of sulfuric acid and 6 to 10 per cent of ferrous sulfate. On dilution the spent liquor combines with water and oxygen to form insoluble ferric hydroxide and sulfuric acid. The acid waste is raised to a pH of 5.5 with soda ash before discharging into the sewers. The suspended solids load on the treatment plant is 1,700 lb. per day as ferric hydroxide. The company pays an average surcharge of $5,580 for suspended solids and a volume waste charge of $3,449.

Summary

South San Francisco is an industrial city producing equal amounts of domestic and industrial wastes. This creates some complex problems which have been worked out with industry.

TOXICITY STUDIES OF METAL-FINISHING WASTES *

By W. D. Sheets

Assistant Research Professor, Engineering Experiment Station, Ohio State University, Columbus, Ohio

Metal finishing has become a major process used by many industries to improve the appearance and/or to add protective coatings to components or finished products. Included in this process are metal plating, anodizing, vitreous coatings, and painting. This paper is concerned only with the metal plating and the toxic effects of the metallic salts on the biological processes commonly used in the treatment of municipal wastes.

There are about 18 principal materials used in plating processes; all are metals with the exception of cyanide. These range from chromium, which is probably the most common, to high-cost metals such as silver and gold. In combination with these principal materials, other compounds are used in making up the plating baths. Cleaning operations, essential to good plating, contribute other compounds which result in a heterogeneous mixture of great variation in concentration. In conducting the toxicity studies, practical limits were not considered.

Hupfer (1) states that wide variation in the volume of metal-finishing wastes exists, ranging from 2,000 to 500,000 g.p.d. It is assumed a metal-finishing plant has a flow of 100,000 g.p.d. entering the municipal system. The total flow at the treatment plant is 1.5 m.g.d., indicating a dilution of 15 to 1. The 35 p.p.m. of copper in the waste would be reduced to 2.3 p.p.m. by dilution. This could be considered a practical limit. The actual toxicity limit as defined for these studies is the concentration at which some effect becomes apparent in the biological processes in use and it may be much higher than the practical limit.

The biological processes consist of the biological filter, the activated sludge process (or combinations of these two) and the sludge digestion process. The first two are aerobic processes while the last is anaerobic. The wastes may have a germicidal effect on these processes, either caused by actual toxicity or because of their acidic or basic qualities.

Literature surveys report wide variation in toxic limits (2). One report stated that chromium ranging from 3.5 to 67.5 p.p.m. in the raw sewage stopped the action in filter beds entirely while a conflicting report states that 100 p.p.m. of chromium reduced the nitrification by 66 to 78 per cent. Such literature survey data may have merit but do not indicate any consistency, or a satisfactory starting point.

In pursuing these studies both laboratory-scale and pilot-plant operations have been used.

Laboratory-scale projects used standard laboratory equipment with one exception and that was the construction of the sludge digestion apparatus for preliminary work on the effect of chromium in the anaerobic process.

The pilot plant consisted of a series of concrete units representing the treatment units used in the majority

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

of municipalities. A flexible piping arrangement made it possible to use the plant as a trickling filter or an activated sludge plant. A separate sludge digestion unit is included. The capacity of the plant was 50 g.p.m. and sewage from a large Columbus, Ohio, interceptor was used as the raw sewage for the plant. Plant effluent was returned to the municipal sewerage system.

Preliminary Studies

Some concept of the toxicity of the various metals used was required to govern the dosage concentration at the pilot plant.

The effect of each metal on the B.O.D. test was used to find a toxic level or relative toxicity.

In the test a synthetic sewage was used, in which 13 g. of lactose broth (Difco) was dissolved in 1,000 ml. of distilled water, 5 ml. of this solution was placed in a test tube, sterilized, and stored until used. When used, one 5-ml. tube of sterile broth was diluted to 100 ml. after seeding with 1 ml. of settled sewage.

A series of B.O.D. bottles were prepared, each containing standard dilution water, 1 per cent of the synthetic sewage, and varying amounts of the metallic salt. The latter was initially prepared as a standard solution of such strength that 1 ml. would correspond to 1 p.p.m. of chromium, copper, nickel, etc. Blanks containing only the synthetic sewage were included in each series.

Using the B.O.D. of the blank as 100 per cent for that series, the per cent recoverable B.O.D. for each concentration of metal would then be calculated from the results of the test run. Plotting the results of several series would present some form of a curve. The curve shown in Figure 1 is that for hexavalent chromium. For comparative purposes an arbitrary point was selected. This was the point at which the curve crossed the 50 per cent recoverable line. Results of these test series gave the values shown in Table I.

Some pH correction was made by buffering the dilution water used in the standard B.O.D. method (3) but as indicated, there were times when no buffering was used. In the case of zinc, the buffer solution was omitted to prevent precipitation of zinc phosphate. In other cases it was omitted in order to find the effect of pH variation.

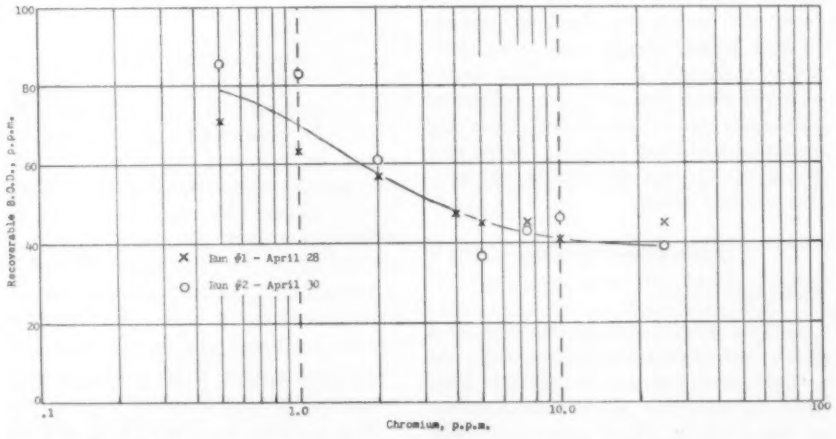

FIGURE 1.—Relationship of recoverable B.O.D. to various chromium concentrations.

TABLE I.—Concentration of Various Compounds Required to Affect B.O.D. Values by 50 Per Cent

Compound	Buffered	Conc. (p.p.m.)
CrO_3	Yes	4.0
CrO_3	No	0.9
K_2CrO_4	Yes	50+
K_2CrO_4	No	10.5
$CrCl_3$	Yes	0.23
$CrCl_3$	No	0.18
H_2SiF_6	Yes	50+
H_2SiF_6	No	2.6
H_2SO_4	No	17.0
$NiSO_4 \cdot 6H_2O$	Yes	16.0
$NiCl_2 \cdot 6H_2O$	Yes	38.0
$Ni(NO_3)_2 \cdot 6H_2O$	Yes	64.0
$NiSO_4(NH_4)_2SO_4$	Yes	134.0
H_3BO_3	Yes	480.0
$ZnSO_4$	No	920.0
NH_4BF_4	Yes	87.0
$Al_2(SO_4)_3$	Yes	18.0
$Zn(BF_4)_2$	No	55.0
NaCN	Yes	3.6
$Zn(CN)_2$	No	0.75
$CuSO_4$	Yes	0.4
$AgNO_3$	Yes	0.3

Bostrom (4) has recently shown that chromate will not affect the pH to any extent whereas a trivalent chromium is sufficiently acid to depress the pH in spite of the buffered dilution water used in B.O.D. analyses. Thus trivalent chromium appears to be more toxic than hexavalent. He has also shown that hexavalent chromium affects the apparent dissolved oxygen content of any liquid containing chromium and requires a correction factor of 0.461 times the parts per million of chromium to be subtracted from the apparent dissolved oxygen. These corrections were not applied in the relative toxicity series.

Pilot-Plant Studies

Biological Filter

Plating wastes can be received as a shock load or as a continuous load. As a shock load, the microorganisms have little opportunity to become immune to the toxicity of a particular salt. It was decided that the shock loading procedure should be applied in the pilot-plant studies and the continuous loading would be used later.

Shock loadings were originally applied for 24 hr. This was later reduced to 12-hr. and then to 6-hr. periods. It was believed that the latter period was more representative of batch dumping.

Using 4.0 p.p.m. as a possible toxicity point, additions of chromium as CrO_3 were applied to the pilot plant. Shock loads were used and approximately 1 p.p.m. of chromium was added initially, increasing by 0.5 p.p.m. with subsequent loadings. The characteristic yellow chromium color became visible at a concentration of about 2.5 to 3.0 p.p.m. At 4 p.p.m. a slight drop in plant efficiency was first noted. The appearance of the filter stone changed; apparently it lost some of the zoogleal growth. No higher concentrations were tried at this time.

Activated Sludge

The activated sludge unit had been completed and it was planned to operate the aeration tank in series with the filter. It was finally determined that the sewage was too weak to support both processes and the activated sludge process was selected for the next study, the filter being taken out of operation.

Additions of chromium as CrO_3 were made at approximately the same concentrations as had been used with the filter. In both cases a definite lag was noted in purging the plant through continued operation between shock loads. About 10 days had been required to reduce the concentration of chromium in the filter plant effluent to a trace. The lag was greater for the activated sludge process. Examination of the activated sludge revealed that the concentration of chromium present was much greater than the dosage rate.

For a shock load test, with a theoretical concentration of 10 p.p.m. of

chromium, the following analytical results were obtained with 24-hr. composite samples:

Item	Chromium (p.p.m.)
Raw sewage	0.19
Settled sewage	8.45
Final effluent	4.38

The chromium had been added for 24 hr. Four hours after starting, a catch sample of settled sewage had 9.39 p.p.m. of chromium. This was assumed to be the maximum rate of addition. A catch sample of mixed liquor at the effluent end of the aeration tank was analyzed and gave 2.19 p.p.m. and 27.39 p.p.m. respectively of chromium in the supernatant and sludge.

Composite samples for the following 24-hr. period gave 0.28 p.p.m., 0.39 p.p.m., and 1.88 p.p.m. of chromium in the raw, settled, and final sewage, respectively. The chromium reported represents total chromium. The chromium in the raw sewage came from spillage since a solution crock and feeder were supported on the weir box and over the raw sewage influent where the plant flows are regulated.

In a 6-hr. shock load run of two weeks, a theoretical addition of 9.6 p.p.m. of chromium gave an additional rate of 6.89 p.p.m. in the settled sewage, and 0.94 p.p.m., 2.24 p.p.m., and 1.31 p.p.m. in the 24-hr. composite samples of raw, settled, and final sewage, respectively. The returned sludge contained 1.75 p.p.m. and the primary settled sludge had 8.34 p.p.m. of chromium. The returned sludge sample was taken at the final settling tank 10 hr. after the start of the run, apparently too soon to show much buildup in the sludge. A sample of the mixed liquor was not taken during this run.

From other data on these runs it has been concluded that a shock load of 10 p.p.m. for 12 hr., or less, has no detrimental effects on the activated sludge process.

Sludge Digestion

The sludge digestion unit of the pilot plant is equipped with a sludge heater-heat exchanger for uninterrupted operation, but currently has no gas storage. Gas generation rates have been the most reliable control but cannot be determined under the present circumstances.

However, on a laboratory scale, Gemmell (5) demonstrated that 100 p.p.m. of hexavalent chromium did not affect sludge digestion, whereas 500 p.p.m. had a very definite effect. Due to equipment failure he was unable to determine the concentration at which the effect began. Gemmell concluded that it would be somewhere between 100 p.p.m. and 500 p.p.m., but would not approximate any closer limits. He did find that analyses of the volatile acids content of the sludge could be used as an indicator of digester activity relative to toxic effects.

Sludge from the pilot-plant tests has been routed through the digester but due to the nature of the plant tests it has not built up concentrations which would be in the range of Gemmell's findings.

Adsorption of the metallic salt by the sludge will require further study with reference to the functions of concentration, time of contact, and solids content of the sludge.

One run was made in which a stock chromium solution was added to 1 l. of mixed liquor, aerated for 90 min. and allowed to settle for 30 min. The supernatant was then analyzed for total chromium. Results are shown in Table II.

Synergistic versus Antagonistic Effects

Any waste containing plating wastes will contain more than one metal. To anticipate the behavior of two or more metals present together, a study was made to observe possible synergistic or antagonistic effects. Chromium, copper, and nickel were selected as the metals of a typical combination.

TABLE II.—Total Chromium in Digester Supernatant

Cr Added (p.p.m.)	Analysis (p.p.m.)	Solids (p.p.m.)
10.1	9.7	3,030
20.2	18.5	3,100
30.3	29.7	2,910
40.4	37.9	2,092
50.5	47.8	2,504

Because of the lack of reproducibility only general statements can be made concerning these studies.

From Table I the relative toxicity values of chromium ($CrCl_3$), copper ($CuSO_4$) and nickel ($NiSO_4$) are 0.23 p.p.m., 0.40 p.p.m., and 16.0 p.p.m., respectively. In a mixture of chromium and copper, the chromium was held to a concentration of 0.23 p.p.m. and the copper was varied. The order was reversed for the second series. In the third series both were varied. Similarly, chromium and nickel, copper and nickel, and chromium, copper and nickel were studied.

These mixtures were used with the B.O.D. test previously described using synthetic sewage as the control ingredient.

For the chromium-copper system, 85 per cent of the samples had a trend toward an antagonistic effect. Individually, the per cent antagonism was generally below 30 per cent and not above 44 per cent.

The chromium-nickel system had a definite synergistic trend. The individual per cent of synergism was high and the antagonism was low, with 53.4 per cent of the samples exhibiting synergistic effects.

The copper-nickel system had questionable results and definite conclusions could not be made. The tendency was toward antagonism.

In the chromium-copper-nickel system, relatively low antagonistic results were obtained in 71.8 per cent of the samples.

Conclusions

Definite conclusions are difficult to arrive at from the data acquired to date. Shock loadings alone have been used in the studies. Variations in the treatment plant, such as sewage strength, sludge concentration, and character of the activated sludge or the zoogleal growths on the filter, are factors that will affect the toxicity limit. Heukelekian and Gellman (6) have shown some of the effects, using manometric apparatus.

Adsorption and coagulation or zeolite action, are also evident. Rudolfs and Zuber (7) worked on chromium, copper and zinc to demonstrate these phenomena.

The original concept of the toxic limit of the biological processes has not changed during these studies and it will be that point at which detrimental effects result in lowered efficiency of the process.

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Stream Pollution

COMPUTATION OF POLLUTION IN THE YAQUINA RIVER ESTUARY

By Wayne V. Burt and Lowell D. Marriage

Respectively, School of Science, Oregon State College, Corvallis, Ore.; and Fish Commission of Oregon, Portland, Ore.

A proposal to construct a pulp mill on the Yaquina River at Toledo, Ore., and to discharge the mill wastes into the river were the motivating factors for a study to determine what the possible distribution of pollution in the affected waters might be. After the study was completed, the decision was made to pump most of the mill wastes to the ocean. The results of the study, however, are of interest in that they may be used as a guide for future pollution studies in the numerous West Coast tidal estuaries which are similar to the Yaquina River estuary.

The Yaquina River is located a little north of the center of the coast of Oregon. Figure 1 shows the specific area under consideration. The principal towns are Newport, with a population of 3,200, and Toledo, with a population of 2,300 (1950 census). Small settlements are located at Yaquina and Elk City. A narrow channel with average depths of more than 20 ft. at mean lower low water runs from the ocean to about one mile above Yaquina, a distance of five nautical miles. Approximately two-thirds of the area of the bay below Yaquina is composed of

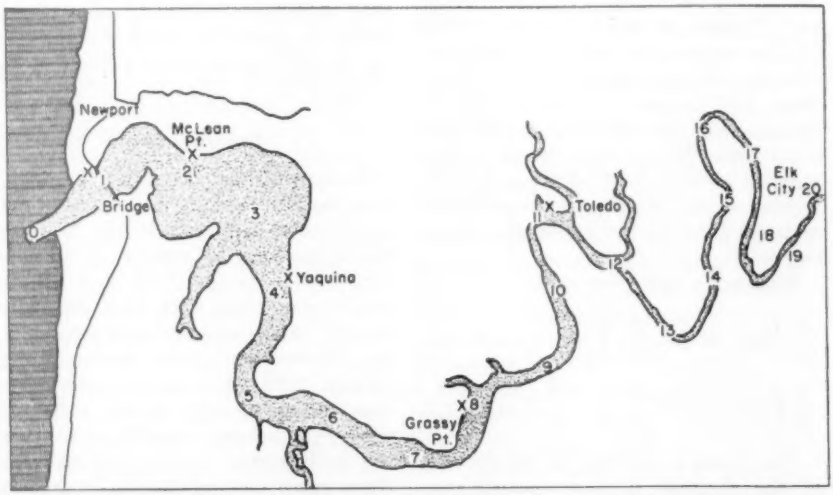

FIGURE 1.—Yaquina Bay and River Estuary, with distances up the main channel shown in nautical miles. Hypothetical outfall positions are indicated by x's.

sand and mud flats, which are exposed at low water. Above Yaquina, the bay narrows to become the Yaquina River. Channel depths decrease to an average of about 10 ft. Only a small part of the river area is composed of sand or mud exposed at low water.

Equations for Pollution Distribution

Stommel (1) has shown that previous attempts (2)(3) to study the problem of the distribution of pollution in an estuary of the type under consideration in this paper have been restricted to the particular estuary under study and are not applicable in general to other estuaries.

Stommel formulated a general set of two equations for the determination of the distribution of pollution which should apply to any well-mixed estuary. The problem is restricted to one dimension, the longitudinal axis of the estuary running from the ocean up the channel to the limit of salt-water intrusion. Stommel's equations are based on the fact that the average steady-state distribution of a pollutant (averaged over a tidal cycle) is a function of the rate at which the river flow carries the pollutant out of the estuary and the rate at which turbulent tidal mixing carries the pollutant back upstream. At any stage of river flow, these two factors or forces tend to balance each other into the steady-state condition. This is true except at the position of the outfall of the pollutant, where the rate of entry of the polluting material into the system must be considered.

Stommel's equations are:

$$\frac{d}{dx}\left(Q\,C - S\,A\,\frac{dC}{dx}\right) + \frac{S}{t}\,C = 0 \quad . . (1)$$

$$\frac{d}{dx}\left(Q\,C - S\,A\,\frac{dC}{dx}\right) + \frac{S}{t}\,C = \psi \quad . . (2)$$

The x-axis is directed along the axis of the channel, positive downstream. The term $Q\,C$ (river flow Q times the concentration of the pollutant C) is the flux of the pollutant toward the sea. $S\,A\,dC/dx$ (cross-sectional area of the estuary S times the coefficient of eddy diffusivity A times the concentration gradient dC/dx) is the net flux of pollutant upstream due to tidal turbulence. The term $S\,C/t$ (t equals 1.44 times the half-life of the pollutant) takes into account the decay of the pollutant. The term ψ is the total rate of pollutant supply at the outfall in pounds per second.

Each of these variables, except A in Eqs. 1 and 2, is known or can be measured at any given point and time and then averaged over a tidal cycle. It is assumed the same regime of turbulence which determines the freshwater and salt-water mixing also determines the mixing of these two and the introduced pollutant. This makes it possible to use Eq. 1 and the freshwater distribution in the estuary to determine values of the diffusivity A throughout the estuary.

The average distribution of the pollutant (over a tidal cycle) can then be computed using the known, measured, and computed data in Eqs. 1 and 2. The solution is carried out by relaxation methods after the equations have been written in finite difference form. Those interested in further details on the method are referred to the work by Stommel (1).

Computation

Stommel's formulas (Eqs. 1 and 2) were used to compute the expected distribution of pollution in the Yaquina River for typical summer conditions with low river discharge and typical winter conditions with high river discharge. For these computations salinity observations were made during August, 1955, when the river discharge was 33.5 c.f.s., and during February when the discharge was 600 c.f.s. During both series of observations relatively small vertical changes in salinity indicated that the estuary was well mixed.

TABLE I.—Reduced Data Used to Compute the Expected Distribution of Pollution in the Yaquina River Estuary

Distance from Ocean (mile)	Area of Section, $S(x)$ (sq. ft.)	August, 1955, Discharge 33.5 c.f.s.					February, 1956, Discharge 600 c.f.s.				
		Average Salinity (p.p.m.)	Eddy-Diffusivity $A(n)$ (sq. ft./sec.)	Computational Results from Eqs. 1 and 2			Average Salinity (p.p.m.)	Eddy-Diffusivity $A(n)$ (sq. ft./sec.)	Computational Results from Eqs. 1 and 2		
				Pn	Qn	Rn			Pn	Qn	Rn
—	—	34,400	—	—	—	—	31.6	—	—	—	—
0	19,000	34,100	1,062	−0.002	0	+0.002	31.0	9,187	−4.722	+9.444	−4.722
1	31,500	33,700	633	−0.004	+0.006	−0.002	30.3	5,419	−4.618	+9.235	−4.668
2	52,500	33,400	235	−0.006	+0.011	−0.005	29.7	3,186	−3.972	+9.050	−5.077
3	46,500	32,600	176	−0.011	+0.020	−0.010	29.0	1,775	−1.393	+4.417	−3.024
4	32,000	31,800	192	−0.015	+0.028	−0.013	27.1	1,230	−0.728	+2.129	−1.401
5	30,000	30,500	138	−0.018	+0.034	−0.016	24.0	820	−0.565	+1.331	−0.766
6	20,500	28,800	153	−0.022	+0.044	−0.021	20.0	840	−0.437	+0.932	−0.495
7	17,900	26,800	138	−0.027	+0.053	−0.026	15.5	727	−0.360	+0.721	−0.361
8	13,500	24,400	153	−0.032	+0.064	−0.032	11.3	735	−0.284	+0.537	−0.253
9	11,300	22,000	162	−0.038	+0.076	−0.038	7.2	714	−0.248	+0.437	−0.189
10	8,300	19,500	190	−0.043	+0.085	−0.042	4.8	845	−0.209	+0.379	−0.170
11	5,600	17,000	251	−0.048	+0.099	−0.050	2.2	650	−0.110	+0.199	−0.088
12	5,900	14,600	201	−0.054	+0.112	−0.057	0.4	230	−0.081	+0.073	−0.012
13	4,100	12,000	240	−0.062	+0.134	−0.071	0.0	0	—	—	—
14	2,800	9,600*	289	−0.076	+0.170	−0.093	—	—	—	—	—
15	2,300	7,200*	276	−0.094	+0.224	−0.130	—	—	—	—	—
16	1,800	5,000*	290	−0.142	+0.332	−0.190	—	—	—	—	—
17	1,400	3,300*	269	−0.182	+0.443	−0.260	—	—	—	—	—
18	950	1,400*	211	−0.257	+0.667	−0.410	—	—	—	—	—
19	500	400*	222	−0.489	+1.079	−0.590	—	—	—	—	—
20	300	0*	—	—	+1.092	—	—	—	—	—	—

* Salinity data extrapolated above Mile 14.

Table I gives the reduced data used to compute the expected distribution of pollution. These data consist of the cross-sectional areas $S(x)$ and average salinities for each mile beginning with 0 at the ocean (Figure 1) and running upstream to the limit of salt-water intrusion. The turbulent eddy diffusivity A, or $A(n)$, for each cross section was computed by use of Stommel's Eq. 6, a finite difference form of Eq. 1 of this paper. Also given in the table are computed values of the coefficients Pn, Rn, and Qn, which are used in Stommel's Eqs. 7 and 7a, finite difference forms of Eqs. 1 and 2 of this paper. The solutions to Stommel's Eqs. 7 and 7a are presented in graphical form in Figures 2 and 3.

The solutions are in the form of curves which show the expected average concentration of pollution as it varies from the mouth of the river upstream to Elk City. The averaging is over a 24-hr. period. Concentration units, on the vertical scale of Figures 2 and 3 are pounds of pollutant per cubic foot of water for each pound of pollutant introduced into the river each second. The horizontal scale on the figures is distance in nautical miles upstream from the ocean. Hypothetical outfall positions for introduction of pollution are indicated by X's on Figure 1, and large dots on Figures 2 and 3. These outfalls were placed at the highway bridge, McLean Point, Yaquina, Grassy Point, and Toledo.

Figure 2 shows expected distributions of pollution for summer conditions. The dashed lines represent concentrations for a pollutant with a very slow rate of decay; the solid lines represent concentrations for pollutants with an arbitrarily selected half-life of four days. In every case, the single curve on the left of each point and the lower curve to the right applies to conditions for the individual outfall.

The concentrations resulting from introduction of material with a half-life of four days would be from one-third to one-fourth, or less than the concentrations for a pollutant with no decay.

It should be noted that concentra-

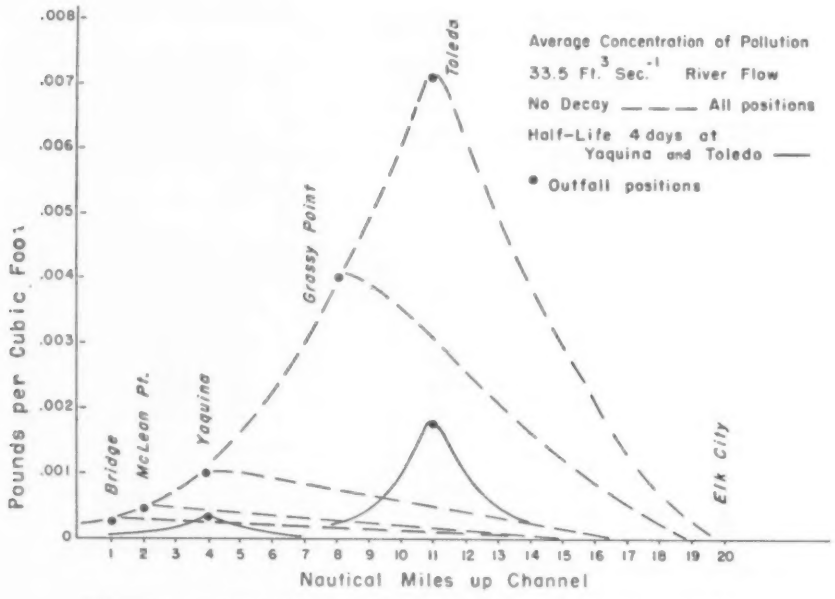

FIGURE 2.—Expected distribution of pollution for summer conditions.

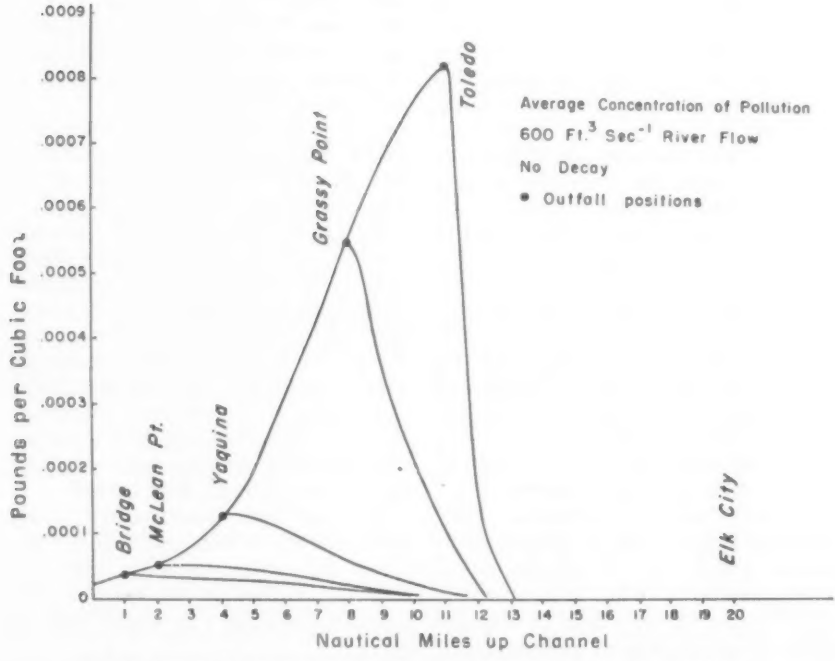

FIGURE 3.—Expected distribution of pollution for winter conditions.

tions near the outfall, as well as concentrations upstream from the outfall, decrease rapidly as the outfall is moved from Toledo toward the ocean. On the other hand, concentrations at any given point downstream from two or more outfalls are independent of the position of the outfalls.

Figure 3 shows expected distributions of pollution for winter conditions for a pollutant with very slow decay. In this case the vertical scale has been expanded to 10 times that used in Figure 2. The maximum concentrations in the sections near the outfalls have decreased by a factor of approximately 10. Due to the increased river discharge, very little pollution would move above Toledo even with the outfall at Toledo. As the outfall is moved seaward, the maximum concentration decreases rapidly; but tidal movement in the widening river and bay will move the pollution well above the outfall positions.

Acknowledgments

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Thanks are due William P. Breese of the Department of Fish and Game Management, Oregon State College, for assistance in the field program. The engineering firm of Cornell, Howland, Hayes, and Merryfield kindly furnished average flow data for the Yaquina River during the period when salinity observations were being made.

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1958 MEMBER ASSOCIATION DUES

Early remittance of 1958 membership dues to the Member Association secretary will assure continued receipt of the Journal. Prior to the mailing of the February issue of SEWAGE AND INDUSTRIAL WASTES the names of members who have not paid their dues are removed from the mailing list. Last-minute payment of dues is often too late to insure uninterrupted mailing of the Journal. Reinstatement is time-consuming and costly to the Federation and its members. In addition, each extra handling of a member's record multiplies the chance for error.

Your cooperation in the prompt payment of dues will insure efficient service. Refer to page 508a of this issue for the name and address of the secretary of your Member Association.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

1956 SALARY SURVEY OF NEW ENGLAND SEWAGE WORKS PERSONNEL

BY JOSEPH B. HANLON, *Chairman*, PAUL MANTER, JR., JOHN O'SULLIVAN, GEORGE CRAEMER, JOHN D. FRAME, AND JOHN R. SZYMANSKI

New England Sewage and Industrial Wastes Association Operators' Salary Study Committee

The New England Sewage and Industrial Wastes Association Salary Study Committee was formed in 1954 to conduct a survey of current wage scales for sewage works personnel, to study organizational structures, and submit recommendations on their findings.

The procedures used and results obtained by other salary study groups in the States of California, Iowa, Ohio, Indiana, Pennsylvania, and New York were carefully reviewed, in addition to the previous salary report of the New England Sewage Works Association, which was published in 1947 (1).

Survey

A questionnaire was prepared that would be used to obtain only such information believed pertinent to the committee's assignment. This questionnaire, which used a uniform classification for job titles to identify exact duties and responsibilities of each position, was distributed throughout New England. To permit a fair comparison of all classes of plants, a limited number of plants adjacent to and outside the New England area were included.

From a total of 153 questionnaires circulated, 76 completed returns were received. This was an excellent showing in view of the difficulties encountered by other committees. However, it was not accomplished without considerable effort. Follow-up cards were used, personal letters, individual contacts in some instances, and finally the help of the various public health officers was enlisted.

Results

Plant data, organizations, present positions, and current salaries were tabulated for Committee study. Special benefits, including paid vacations, sick leave, overtime pay, and prevalence of retirement plans were also secured for study. Additional miscellaneous information considered important because of its influence on wage scales in sewage treatment plants was also accumulated.

Perhaps of greatest importance was the reply received to the question: "Do you favor compulsory certification?" Approximately 64 per cent answered "yes," 16 per cent, "no," and the remaining 20 per cent had no reply.

Basis of Evaluation

The problems in evaluating salaries for sewage works personnel are many. First, it is a specialized field. There are great variations in types and sizes of plants which are often classified alike. These differentials are most

prominent in the Grade V, VI and VII categories. Positions under similar job titles frequently have entirely different duties and responsibilities. It is suggested, therefore, that these points be kept in mind when studying the results of the survey.

For salary statistics the U. S. Department of Labor, the Massachusetts Division of Necessaries of Life, and the Division of Labor Statistics were contacted. Public utility workers in gas and electric companies were selected for comparison with sewage works personnel. Both serve public utilities and their job classifications are identical in many instances. Each group requires shift work and, with limited exceptions in the sewage treatment plants, the groups compared are productive workers.

Discussion

The average weekly wage increase between August, 1945 and August, 1956 for the group of 3,413 workers surveyed was 85.76 per cent. The year 1945 was selected as the base year to permit use of the latest available salary data as gathered in 1946 by the New England Sewage Works Association Salary Study Committee (1). Furthermore, salaries for public utility workers for that year were in agreement with the prevailing cost-of-living wages.

If the same 85.76 per cent increase enjoyed by public utility workers were applied to the 1945 salaries being paid sewage works personnel as listed in the 1946 report, the results would still be substantially below the utility group. This may be attributed to the fact that annual salaries of sewage works personnel in the base year were 23 per cent lower than the utility employees.

A comparison of what has happened in sewage treatment plants outside of the New England area is also possible because certain plants were surveyed at both times. One of these is the Washington, D. C., plant, which had the salary increases shown in Table I.

TABLE I.—Comparison of 1946 and 1956 Salaries, Washington, D. C., Sewage Treatment Plant.

Position*	1946 Salary	1956 Salary	Increase (%)
Superintendent	$6,020	$10,065	67.2
Asst. Superintendent	5,180	8,645	66.9
Chemist	4,300	7,465	73.6
Asst. Chemist	3,640	6,250	71.7
Laboratory Technician	1,968	3,470	76.3
Storekeeper	2,298	3,925	70.8
Chief Operator	3,640	6,364	74.8
Shift Operator	2,870	5,491	91.3
Engineman—Oiler	1,902	3,994	110.0
Laborer	1,590	3,120	96.2
Maintenance Engineer	3,640	6,364	74.8
Machinist	2,690	4,929	72.1
Clerk—Stenographer	2,100	3,685	75.5
Chauffeur	1,750	3,952	97.3
Bacteriologist	—	5,335	—

* Total number of employees increased from 75 to 94 during the period.

The Washington, D. C., salaries are in agreement with 15 other major Grade VI and VII plants recently surveyed throughout the United States. These plants showed maximum average annual salaries of $10,502 for the first position, and $8,299 for the second position.

With but few exceptions, current wages paid in the New England plants continue to be sub-standard. Out of 629 positions, 161 (26 per cent) receive annual salaries of less than $3,000, hardly a living wage for the year 1956. The annual average salary for 136 plant operators in 48 different plants throughout New England was $3,524.50. Furthermore, 79 per cent of the plants surveyed reported all maintenance work done by plant force.

It is recognized that this field of work attracts individuals who desire a degree of security. The work is specialized and not always pleasant in nature.

Many of the plants are under Civil Service, which requires that preference in promotions be given to employees in the lower grades. With or without

Civil Service, it is in the public interest to attract the highest type of individual in the beginning and to retain him as he advances in grade and experience. To accomplish this, the committee recommends that in every case the basic salary for a particular position be commensurate with that paid by the public utility serving the area. Furthermore, the salary shift differentials for other than the day shift should be paid; the amount based on individual duties and responsibilities involved.

In the New England area the returns from the questionnaire show that educational requirements are open with but few exceptions. Where Civil Service is in effect, ability to pass the prescribed examination for the position is the entrance requirement. Seventeen plants reported certification as a condition of employment for superintendent and/or operator position. Based on these results, it is the opinion of this committee that high educational requirements or equivalent training and experience cannot be rigidly set or justified until such time as definite entrance requirements and/or compulsory certification, administered by a recognized supervisory agency, are established.

Classifications

The classifications of sewage treatment plants used in the following recommended wage scales are similar to the proposed grades now under consideration by the Commitee on Certification of the New England Sewage and Industrial Wastes Association (Appendix I). Both committees are aware of the difficulties encountered when attempting to apply the existing classifications throughout the range of plants located in New England. The need for a more accurate simplified up-to-date method of classifying plants is apparent.

Something had to be done to close the range between the small town complicated plant which previously qualified as a Class A plant and the large plants, equally complicated but serving one or several cities. Under the new system of grading plants, a much closer and more accurate classification with appropriate wage scales will be possible for each size and type of plant.

Recommendations

Plant Classifications

The minimum annual starting salaries recommended for qualified sewage treatment plant superintendents and operators are based on classification of the sewage treatment plants as follows:

Grade I Plants

1. All plants serving up to 5,000 population, except those employing chemical precipitation or activated sludge.
2. Those plants serving up to 15,000 population which do not employ any of the following:

   a. Separate sludge digestion with gas collection.
   b. Mechanical dewatering or sludge incineration.
   c. High-rate trickling filters.
   d. Highly mechanized or specialized methods of sewage treatment.
   e. Chemical precipitation.*
   f. Activated sludge.

Grade II Plants

1. Those plants serving under 5,000 population employing chemical precipitation or activated sludge.
2. Those plants serving 5,000 to 15,000 population employing one or more of the methods, 2a through 2d, for Grade I plants.
3. Those plants serving 15,000 to 50,000 population which do not employ any of the methods, 2a through 2f, for Grade I plants.

Grade III Plants

1. Those plants serving 5,000 to 15,000 population employing chemical precipitation or activated sludge.

* To obtain B.O.D. removals in excess of 70 per cent and suspended solids removals in excess of 80 per cent, from raw sewage.

2. Those plants serving 15,000 to 50,000 population employing one or more of the methods, 2a through 2d, for Grade I plants.

3. Those plants serving 50,000 to 100,000 population which do not employ any of the methods, 2a through 2f, for Grade I plants.

Grade IV Plants

1. Those plants serving 15,000 to 50,000 population employing chemical precipitation or activated sludge.

2. Those plants serving 50,000 to 100,000 population employing one or more of the methods, 2a through 4d, for Grade I plants.

Grade V Plants

1. Those plants serving 50,000 to 100,000 population employing chemical precipitation or activated sludge.

2. Those plants serving 100,000 to 200,000 population employing one or more of the methods, 2a through 2d, for Grade I plants.

Grade VI Plants

1. Those plants serving 100,000 to 200,000 population employing chemical precipitation or activated sludge.

2. Those plants serving 200,000 to 500,000 population employing one or more of the methods, 2a through 2d, for Grade I plants.

Grade VII Plants

1. Those plants serving 200,000 to 500,000 population employing chemical precipitation or activated sludge.

2. All plants serving more than 500,000 population.

Salaries

The recommended minimum starting salaries for qualified sewage treatment plant superintendents and operators are given in Table II.

Certification

Where a program of operator certification has been established, there reportedly have been improvements in the quality of plant operation and in salaries. The committee favors a program of compulsory certification for supervisory personnel. Such a program should be sponsored by a responsible organization.

TABLE II.—Recommended Minimum Annual Starting Salaries

Plant Classification (Grade)	Salary ($)	
	Superintendent	Operator
I	3,900	3,900
II	4,400	4,100
III	5,100	4,300
IV	6,100	4,600
V	7,200	5,000
VI	8,500	5,400
VII	10,500	6,100

Training Programs

In-service training programs sponsored and financed by the employing agency are recommended as the best means of preparing employees for increased responsibility and advancement in the specialized field of sewage treatment. In particular, attendance is advocated at special short courses for sewage plant operators, which are offered by many state public health departments.

Future Surveys

It was apparent to the committee that future salary surveys should be conducted at two-year intervals. If adopted, this practice would show to a degree the value of the present studies and indicate the effectiveness of any certification program that might be undertaken.

Acknowledgments

The helpful cooperation of superintendents, operators, state health officials, Association officers, committee chairmen, and others who participated in the salary study is sincerely appreciated.

Reference

1. "Salaries for Sewage Treatment Plant Operators." *Sewage Works Jour.*, **19**, 2, 259 (Mar., 1947).

APPENDIX I.—PROPOSED QUALIFICATIONS FOR NEW ENGLAND SEWAGE WORKS PERSONNEL *

Six grades of operators are proposed to be established to parallel the previously described classification of plants, not including, however, Grade VII plants. Those officials responsible for appointment of an individual to supervise operation of a Grade VII plant will find men qualified for such position among the ranks of those certified as Grade VI operators.

Grade I certified operators shall be considered as qualified to supervise operation of Grade I plants; Grade II certified operators shall be considered as qualified to supervise operation of Grade II plants, etc. Operators working under the supervision of the superintendent, and who normally have charge of, or perform important operating functions will be expected to hold certification at least as high as two grades below that required of the superintendent.

General Requirements

Applicants in all classifications shall meet the following general requirements:

1. Be in satisfactory physical condition.
2. Be able to read and write the English language.
3. Produce evidence of satisfactory completion of educational courses available and recognized by the Certification Committee consistent with the grade applied for.
4. Be able to maintain desirable logs and records of operation and maintenance in a treatment works of classification consistent with the grade applied for.
5. Produce evidence satisfactory to the Certification Committee of ability and experience in handling men and dealing with the public to a degree consistent with the requirements of the grade applied for.
6. Produce evidence satisfactory to the Certification Committee of (a) satisfactory moral character, (b) integrity, (c) ability to cooperate with others, and (d) industriousness, initiative and judgment to a degree necessary to secure satisfactory operating results.

Educational Requirements

Education may be substituted for a portion of the experience as required and to the degree indicated here:

1. Grade I—no substitution.
2. Grades II, III, IV, V, and VI as given in Table III.

Also, various other educational attainments will be considered as experience to the degree adjudged proper by the Certification Committee.

TABLE III.—Education Substitute for Experience

Education	Experience Equivalent (years)
High school graduation	2
B.S. in sanitary, chemical or public health engineering	5
B.S. in civil, mechanical or electrical engineering	4
B.S. in chemistry or bacteriology	4
B.S. In other fields	3

Operator Classifications

Grade I Operator

All applicants for this grade must submit satisfactory evidence of at least two years of experience in responsible charge or in operation of a plant in this, or higher grade. Educational attainment shall be satisfactory to the Certification Committee.

* Prepared by the New England Sewage and Industrial Wastes Association Voluntary Operators' Certification Committee; Walter M. Kunsch, Chairman, Thurman W. Dix, Clarence V. Hickey, Thomas A. La Cava, Richard M. Power, and Edwin M. Thayer.

Grade II Operator

All applicants for this grade must submit satisfactory evidence of at least four years of experience in responsible charge of a plant in Grade I or higher; or of four years of experience in operation of a plant in Grade III or higher; and must submit satisfactory evidence of mechanical or chemical aptitude. Higher education may be substituted for no more than three years of experience.

Grade III Operator

All applicants for this grade must pass a Grade III examination, must submit satisfactory evidence of at least six years of experience in responsible charge of a plant in Grade II or higher; or of six years of experience in operation of a plant in Grade IV or higher; and must at least be a graduate of elementary school (8 grades completed) with mechanical or chemical aptitude. Higher education may be substituted for experience to the degree indicated under Educational Requirements.

Grade IV Operator

All applicants for this grade must pass a Grade IV examination, must submit satisfactory evidence of at least eight years of experience in responsible charge of a plant in Grade III or higher; or of eight years of experience in the operation of a plant in Grade V or higher; and must have an education equivalent at least to that of a high school graduate, which mechanical and chemical aptitude. Higher education may be substituted for experience to the degree indicated under Educational Requirements.

Grade V Operator

All applicants for this grade must pass a Grade V examination, must submit satisfactory evidence of at least 10 years of experience in responsible charge of a plant in Grade IV or higher, or of at least 10 years of experience in the operation of a plant in Grade VI category, and must have an education at least equivalent to that of a high school graduate, with mechanical and chemical aptitude. Higher education may be substituted for experience to the degree indicated under Educational Requirements.

Grade VI Operator

All applicants for this grade must pass a Grade VI examination; must submit satisfactory evidence of at least 12 years of experience in responsible charge of a plant in Grade V or VI; must have a college education with Bachelor's degree in one of the fields for which four or more years of "experience equivalent" is allowed, except under those unusual circumstances where self-education of an individual can be accepted as a satisfactory substitute by the Certification Committee; and must have a high degree of mechanical and chemical aptitude. Higher education may be substituted for experience to the degree indicated under Educational Requirements.

ACCIDENT PREVENTION *

By E. L. Macdonald, Jr.

Sewage Works Supervisor, East Bay Municipal Utility District, Oakland, Calif.

Accidents are preventable! Through ignorance or misunderstanding many persons believe an accident to be the result of fate. This belief is untrue in that it fails to consider the cause and effect of accidents. In other words, accidents do not occur without a cause.

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

The process of identifying, isolating, and controlling these causes is the keystone of accident prevention. Progress is being made in controlling some natural elements which cause accidents. It is only such accidents as are caused by lightning, storms, and floods which are difficult or practically impossible to prevent. These accidents comprise only a small percentage of the total number of all the accidents and are rightly classified as being "Acts of God."

A preventable accident may be traced to causes originating in the heredity and early environment of the individual. These causes may appear as actions which make the worker accident prone. No matter how good an accident prevention program is, an accident prone worker is difficult to handle.

The elimination of unsafe acts and unsafe conditions, offers a simple and effective means of preventing accidents. Three facts about unsafe acts and conditions are that they:

1. Usually can be anticipated.
2. Are easily identified.
3. Can be eliminated upon discovery.

For these reasons, all practical accident prevention measures must be designed to prevent or eliminate unsafe acts and unsafe conditions.

Safety Engineering

Engineering methods must be employed to prevent or eliminate unsafe conditions. The design, construction, installation, and maintenance of equipment and facilities must follow safe engineering practices. Unsafe conditions already existing may be eliminated through mechanical revision or structural modification. Engineering devices can be developed to correct unsafe conditions and in some cases to prevent unsafe acts. In general, safety engineering makes a safe working area to the extent that a minimum of physical hazards exist.

Safety engineering prevents accidents in numerous ways, depending on the nature of the hazards. It makes use of scientific principles to make a work area safe. The four basic ways to accomplish this are: replacement, elimination, revision, and relocation. Machine guards, automobile brakes, traffic signals, pressure relief valves, and hand railings are varied examples of engineering for safety.

Safety Education

Safety education is one of the most important phases of accident prevention. Through safety education safe attitudes are developed. It is essential that the safety consciousness developed through education be supplemented by instruction in safe habits, practices, and skills. Safety education can help prevent those types of accidents that cannot be controlled by engineering, supervision, or enforcement. A safety program will be no better than safety education.

The most important advantage of safety education is that it develops a safety consciousness in the employee, which when properly instilled will cause the employee to act safely even without safety devices. In a sense, each accident points out a deficiency which should have been corrected. Many of these deficiencies cannot be eliminated by any other means except safety education.

A safety education program must be based on sound methods and directed specifically at the hazards most important to a particular group of workers. After specific instruction, the program should be devoted to general safety topics. Methods will vary depending on the work. Lack of facilities, instructors, or time may be limiting factors.

Safety meetings should be scheduled so that they conflict as little as possible with the normal plant operation. Plant personnel can be used as instructors in large plants. In small plants

the responsibility rests with the superintendent; he must understand his subject. Visual aids, such as mock-ups, moving pictures, slides, charts, diagrams and blackboards can be used effectively. All pertinent points should be demonstrated while being discussed. Worker participation in the demonstrations is desirable. Bulletins, pamphlets, or other material that benefits the accident prevention program should be circulated among the staff.

Training

Training is a part of education, actually being a specialized form of education used to prepare a worker for a specific activity. Proper training will enable a worker to work safely without constant supervision. The worker must receive specific instructions so that he will be fully aware of the hazards involved and will know how to eliminate them.

Safety training must be carried out concurrently with job training. Safe habits, learned as an essential part of the job, will help prevent accidents. Safety practices must be incorporated into regular job training methods and the required training must be carefully planned around the particular job. To do this the job must be analyzed with particular attention to the hazards involved.

Some hazards can be eliminated by a revision of the operating instructions. Those hazards remaining can be guarded against by safe operating practices. Consider the worker. What are his personal qualifications? Is he equipped to do the job safely, or must he have special training? Instruction must be planned so that the worker is impressed with the importance of safe habits and practices under actual working conditions. In order that crews are trained to handle emergencies as they arise, it will be necessary to simulate certain emergency conditions. Important procedures must be emphasized and repeated if not clearly understood. A clear understanding of the reasons for particular safety practices is essential. Follow-up checks should be made, and additional training or retraining provided whenever necessary.

Without competent supervision some laxity of safety standards will result. Supervisors must provide continuing instructional assistance and guidance to workers. This assistance and guidance will be of great value in controlling unsafe acts and conditions.

All supervisors must have sufficient authority to require compliance with safety standards where necessary. All safe practices must be adhered to by the worker. When a worker fails to comply with safe practices, although aware of them, the supervisor must then resort to means of enforcement. In principle, enforcement is an undesirable accident prevention control. The use of enforcement may indicate a deficiency in engineering, education, training, or supervision. However, enforcement may prove effective where other controls fail. If the training is good and the habits well developed the workers will work safely with or without supervision.

Supervision

Some supervisory personnel are inclined to fix blame rather than to eliminate the cause of the accident. This type of approach will result in "covering-up" tendencies by the employee. This behavior can be very detrimental to an accident prevention program. Cause will usually indicate blame, if any. Only after eliminating the hazard and providing proper training should enforcement be considered. The important principles of safety supervision are to:

1. Establish standards.
2. Plan programs.
3. Correct violations.
4. Study causes of violations.

Accident prevention controls cannot be applied effectively with hit or miss

methods. Engineering, training, supervision, and enforcement measures must be based on factual evidence. It is essential that all the facts relating to unsafe acts, unsafe conditions, and accidents be collected and studied to determine which method will prove most valuable.

Accident Data

All information related to unsafe acts, unsafe conditions, and accidents should be carefully recorded to facilitate use. Recording these facts only is of little value in accident prevention work. The use of data is the basic principle of accident prevention. The gathering of facts must be a continuous task of all personnel. Data may be obtained by accident investigations, safety inspections, conferences, and conversations.

It should be restated that accident facts are worthless if stored in files. Accident facts must be analyzed to try to find conclusions that may be used in the accident prevention program. Any suitable method may be used to focus attention on the unsafe acts. The analysis may be restricted somewhat by the type of organization. However, regardless of the size of the organization all accidents should be studied. The conclusions derived from accident data will help in planning a long range program. If the conclusions are sound, the attack well planned, and the corrective measures effective, the accident prevention program will succeed and accidents will be reduced.

INTERIOR PHOTOGRAPHY OF SEWERS

One of the most important functions performed by personnel responsible for the maintenance and operation of any sewer system is the job of interior inspection. This work is done to determine the existing condition in the system and, when trouble develops, to ascertain what the problem may be. As a sewer line becomes older, many physical changes take place; deterioration of the interior surface, misalignment due to poor construction or trench preparation, failure of the joints with consequent excessive groundwater infiltration, and numerous other conditions. These eventually cause trouble or even complete failure of certain sections of the sewer. Sooner or later it becomes necessary to make a detailed inspection of the interior.

Sometimes it is possible to make an interior inspection without undue difficulty—particularly in modern systems which have been constructed with these needs in mind. In some older systems, which have been in service 30 to 40 years or longer, little thought seems to have been given at the time of construction to future needs with respect to maintenance, inspection, and cleaning. In such cases, the task of interior inspection may be very difficult.

Inability to obtain satisfactory or conclusive results is due, in many instances, to the existence of physical factors not anticipated or beyond the control of the person making such an investigation. Even under normal conditions, however, the investigator is not always satisfied with what he has observed. As one of them said, when told he should be able to look up a pipe at least 100 to 200 ft., "You may be looking, but you sure aren't seeing."

Some of the factors which may prevent a successful interior investigation are the following:

1. Distant spacing of manholes. In some large interceptor sewers, which have been in service for many years, the distance between manholes may be as much as 2,500 ft.

2. Curves in the line. In some old lines there are many curves, necessitated by drainage or easement problems, which unfortunately may be just adjacent to an existing manhole.

3. Haze or steam in the lines, caused by ground fog or hot discharges into sewer lines.

4. Bad atmospheric conditions.

5. Poor light.

6. Poor construction of many manholes which makes it difficult or impossible for the investigator to position himself within the area available.

Photographic Method

The answer to most of these problems is a better way of seeing which is not, "just looking." Interior photography of sewers seems to offer such a method of inspection which is both effective and practical. Also, when it is considered in relation to the original cost of sewer line construction, the method would appear to be economical as well.

The use of photography for the purpose of sewer inspection is relatively new, going back no further than two or three years. These same years, however, have seen so much technical advancement in the development of photographic materials that it is now possible to obtain excellent results in the photographing of sewer lines. Many problems peculiar to this use of photography, which caused great difficulty in the early years, have been satisfactorily solved by redesign of the necessary equipment.

This new tool can be advantageously used by the engineer to obtain a clear evaluation of the interior condition of many lines. With it he can:

1. Examine the condition of the joints for possible misalignment.

2. Observe the condition of interior surfaces to determine the amount of corrosion which exists.

3. Locate with great accuracy the position of house connections and laterals at the point of entrance into the main pipe.

4. Pinpoint weak spots, through study of the small thread-like cracks which may appear in the photographs,

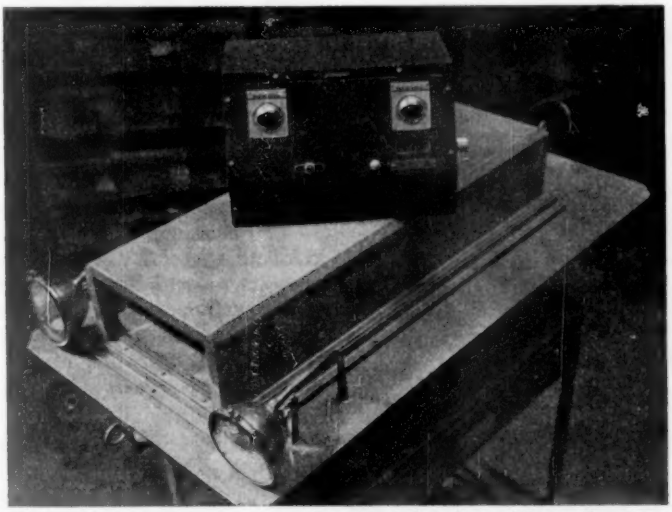

FIGURE 1.—A camera boat used to photograph interiors of large-diameter sewers.

and determine their significance by air testing and other methods.

Equipment

Many types of camera boats are used and designs are constantly being improved. Figure 1 is a photograph of a boat which has been successfully used in the examination of relatively large sewer lines.

A number of variations of the camera boat have been developed. In some the camera and light, which are housed as a unit, are pontoon-mounted with the battery units located under the top housing. The upper surface of the front part of the boat is painted black to stop reflection. Glass, in front of both the light and the camera is kept clear of condensation by the heat of the illuminating light. The illumination is a stroboscopic light which is encased in a leak-proof box. Front and rear tag lines may be used to guide the boat in a straight line, preventing side-sway and providing an additional safeguard in permitting withdrawal of the boat in the event of trouble.

Figure 2 shows the actual appearance of a torpedo-type camera boat, plus a photograph of a one-piece photographic unit which was used in the early days of sewer line photography. The torpedo-like hulls of the boats used in smaller sewers are usually constructed of stainless steel and fiberglass. They are very durable and can take much hard usage.

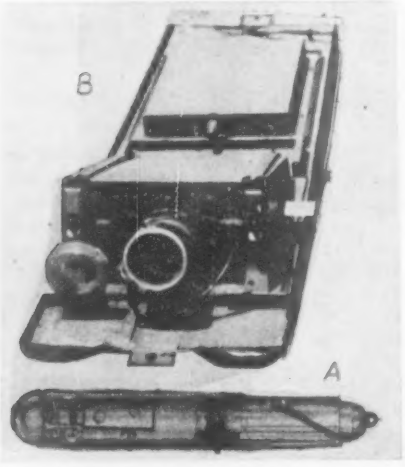

FIGURE 2.—Torpedo-type camera boat (A) and an early model photographic unit (B).

For use in larger sewers, a torpedo-type hull may be constructed of styrene, a light but bouyant material. The illuminating light and reflector, located in the front of the boat, and the camera, mounted in the rear, are both activated by dry batteries located under the sealed area in the center of the ship. The cameras, which are constantly being improved, are already capable of taking pictures of a full 180° field of vision and using color film.

Operation

A light but durable A-frame type of hoist, containing a cable drum sufficient in size to hold 4,000 ft. of waterproof, plastic-coated cable of high tensile strength, is positioned above the entrance to the upstream manhole (Figure 3). The camera boat is then lowered and placed in the flow of the sewer. One end of the plastic cable is then connected to the boat by means of a cannon-plug type socket. The cable is passed over a small 12-in. pulley drum to which a footage-counting device is connected. The cable drum may then be reeled out to permit the camera to travel the desired distance without any further preparation. Sometimes, when the velocity of the flow is so slow that it fails to move the camera at the desired speed, a second hoist is positioned over the downstream manhole and used to pull the unit through the line at the desired speed. This conserves time and provides an additional safety factor.

The camera is activated by pressing a contact-type button arranged on the hoist. This button activates the device situated in the camera boat and an ex-

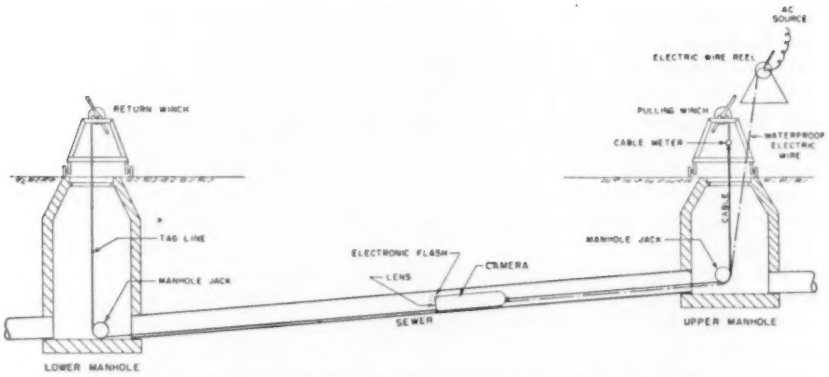

FIGURE 3.—Diagram of sewer photography procedure.

posure is made. Then the cable is reeled out the desired distance and the performance is repeated. A record of the position of the photographic equipment in the sewer line is recorded through an accurate footage-metering device which enables the operator to know at what position in the sewer each photograph was taken. This record can then be outlined on a profile sheet to enable the engineer to pinpoint on the surface the physical location of any particular photographed area.

When feasible, it is recommended, as an additional safety measure, that a sewer ball be passed through the line prior to photographic inspection.

Los Angeles Experience

Portions of the Los Angeles sewerage system have been in use for many years and a variety of ills have begun to beset them. In many of these lines physical inspection is virtually impossible and unsatisfactory at best. Therefore, it was decided to make a photographic inspection of some of the affected areas. Two companies specializing in the work were employed. Each had developed its own equipment and appurtenant methods of operation. Both were able to supply excellent pictures, in black and white and in color, which were extremely helpful in evaluating the present condition of the sewers inspected.

Problem Area

The immediate situation which precipitated the decision to obtain the services of an organization having suitable photographic equipment was concern about a particular section of line. An adjacent city discharges its sewage into one of the larger Los Angeles trunk sewers through a force main which terminates in the large sewer 40 to 50 ft. downstream from the nearest manhole. The discharge of large quantities of raw sewage at right angles to and above the normal flow of the trunk sewer resulted in considerable turbulence and in the release of hydrogen sulfide gases. Previous experience indicated that immediate attack does not always occur under such circumstances but that instead there may be deterioration in the line downstream from the point of entry.

Visual inspection revealed some evidence of attack around the end of the pipe and on the wall opposite the discharge but this did not appear to be of a serious nature. However the sewer was of rather shallow depth and located under a heavily traveled roadway subject to considerable vibration by heavy truck travel. It was felt that, if gas deterioration was severe

in the portion of the line which could not be inspected visually, complete collapse of the pipeline was a real possibility. So, even though the tile at the lower manhole appeared to be in good condition and the construction plan indicated sufficient original thickness of wall, it was decided that interior photographic inspection was indicated.

The line in question was a 60-in., semi-elliptical, tile-lined sewer, flowing better than half full at peak flow. Prior to launching the camera boat, the periodic discharge of sewage from the force main was determined in order to ensure the best possible conditions within the sewer at the time photography was undertaken and to eliminate unnecessary problems while floating the camera downstream. The whole process of taking pictures of this section of line, once the boat was launched, required only a few minutes. No unexpected problems were encountered and few should be expected if the program has been well planned and any unusual physical difficulties in the line have been predetermined.

Results

Photographs of excellent quality were obtained, in both black-and-white and color. Examination of these indicated:

1. Poor construction work in joining the force main to the trunk sewer. The hole was made by use of a jack hammer with the result that adjacent tile was knocked off, exposing the concrete wall to attack by sewer gases. This haphazard method of making such a connection has been eliminated as a result of the picture taken of this condition; contractors are now required to core the opening and place protective material around the edge of the entering pipe.

2. No serious deterioration of the pipe immediately downstream from the discharge.

3. Beginning of deterioration, as a result of the released gases, at a point slightly farther downstream. Some tile liners were lost and some destruction of the exposed concrete was noted.

4. Severe deterioration at the next point of observation. No tile remained and only a part of the original lugs were to be seen, indicating fairly deep penetration of the outer concrete wall.

5. Extreme deterioration farther along the line. No lugs remained on the tile, indicating penetration at least 2 to 4 in. in depth.

6. Improvement in the condition of the interior as the lower manhole was approached. The tile face showed some slight spalling but, in general, the condition of the line appeared satisfactory.

As a result of these pictures the zone of deterioration was clearly ascertained. With this knowledge it was possible to know with exactness the remedial steps which should be undertaken. A series of core holes were drilled through the concrete lining from the surface of the street to determine its precise thickness in case repair was needed. In addition, the entrance of the force main to the sewer was redesigned to minimize the turbulent discharge.

The detailed report made on the conditions found in the sewers photo-

FIGURE 4.—Interior of a 27-in. sewer. Note high and low flow lines.

FIGURE 5.—Tuberculation in a 27-in. cast iron sewer line.

graphed would not be of general interest but one or two of the photographs made can be reproduced here as an indication of the results which may be expected from such a survey.

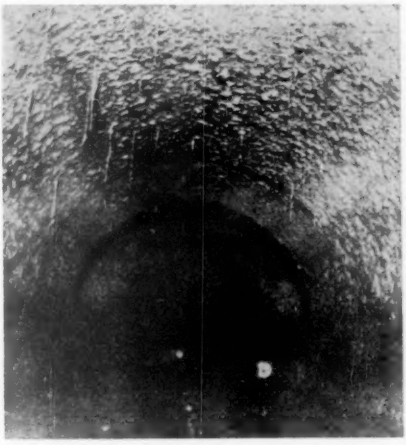

FIGURE 6.—Cave-in of a 17-in. sewer line.

Figure 4 is a photograph of a 27-in. line showing the high and low flow lines. Figure 5 shows tuberculation in a 27-in. cast iron pipe sewer line. The knobs and incrustation shown indicate the extent of tuberculation that has taken place during the life and use of the pipe. The information obtained from this and other pictures of the area, incidentally, formed the basis for a report requesting its immediate replacement.

Figures 6, 7, and 8 are shots of the interior of a 17-in. vitrified clay sewer pipe. Figure 8 shows a house connection.

Color Photography

It is unfortunate that it is not possible in this paper to reproduce samples of the many color photographs and slides which were made of the Los Angeles sewers. It is important to emphasize that these make available data

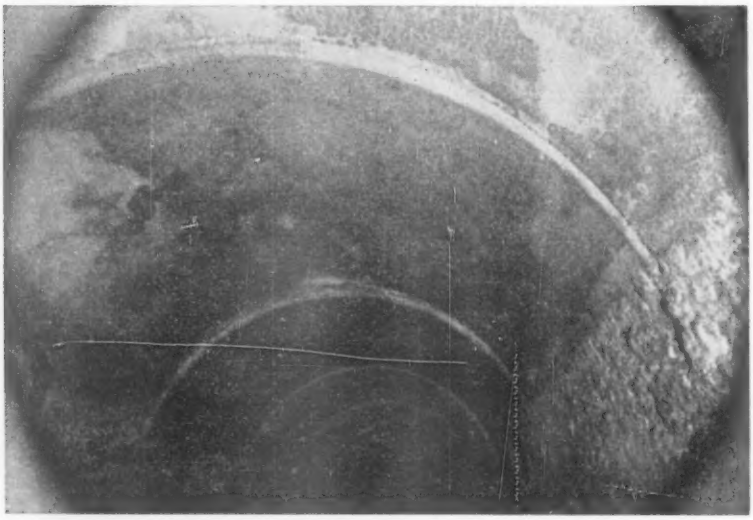

FIGURE 7.—Interior view of a 17-in. sewer line.

FIGURE 8.—Photograph of a 17-in. clay pipe sewer showing joints and a house connection.

TABLE I.—Cost of Film Purchased and Processed by Owner of the Photographic Unit *

Black-and-White		Color	
Per Frame ($)	Per Foot ($)	Per Frame ($)	Per Foot ($)
0.03	0.24	0.20‡	1.62

* Costs include initial cost of film, processing, positive projection print, structural analysis of pictures, and mailing.

which cannot be obtained from black-and-white photographs. They enable corrosion engineers to analyze the recorded color differentials and determine the type and quantity of the organic slimes existing on the photographed surfaces. Bacterial corrosion is an ever-increasing problem and can effect incalculable damage.

Costs

Presumably costs of interior sewer photography vary with the organization employed and the community in which the sewer is located. The necessary equipment for making photographic sewer surveys may be leased by the month or by the year.

One California company puts the cost of leasing at about $100 per month or $1,200 per year. This cost includes complete instruction in the operation and care of the unit. The purchase and processing of film and the cost of other supplies would, of course, be in addition to the rental. If film is purchased and processed by the lessor of the unit, the costs quoted by this company as of June, 1957, are as given in Table I.

Table II gives cost of sewer photography in sewers of various dimensions if the work is done entirely by the organization owning the equipment.

TABLE II.—Complete Cost of Photographic Survey Done Entirely by Outside Organization

Diameter of Line (in.)	Black-and-White Film ($/sewer mile)	Color Film ($/sewer mile)
8	158.40*	1,069.20*
17–27	31.68†	214.04†
27–36	15.84‡	106.92‡
36–64	10.56**	71.28**

* Based on one exposure per foot.
† Based on one exposure every 5 ft.
‡ Based on one exposure every 10 ft.
** Based on one exposure every 15 ft.

Conclusions

The use of photography as a tool for the interior inspection of sewers is of demonstrated value. Obviously, however, the value of this new technique must be balanced against the economic factor involved. In some cases the cost will necessarily be high, especially when information is desired about short distances of line. Even in such instances, however, these costs may not be excessive when compared with all the costs involved in other more laborious methods of inspection—which may be less effective and certainly do not provide the advantage of having a permanent visual record.

The photographic method of pipeline inspection has great merit and possesses almost unlimited possibilities. Its use should be given serious consideration by all personnel responsible for sewer line maintenance. In cities where funds for this purpose can be provided, it would be advantageous to set up a program of picture taking to provide periodic checking of suspected lines to determine progressive deterioration.

Acknowledgment

The helpful cooperation of A. A. Appell, Superintendent, Sewer Maintenance Division, Bureau of Sanitation, Los Angeles, Calif., William Ulrich, Sub-Surface Photo Company, Los Angeles, Calif., and C. Sketchley, Rodding-Cleaning Machines, Inc., Los Angeles, Calif., is sincerely appreciated.

TIPS AND QUIPS

Nebraska Sewage Treatment Status

The Nebraska plains have been experiencing a boom in sewage treatment plant construction. From 1952* to July 31, 1956, 37 treatment plants were constructed at a cost of $1,645,526. Since July 31, 1956, the start of federal aid to sewage treatment plant construction, 23 applications for construction, costing $6,334,440, have been submitted. The federal government has or will contribute $1,279,066. No longer can Nebraska be criticized for lack of progress in sewage treatment plant construction.

Operator Recognition

Recognition of the sewage treatment plant operator and his contribution to the community and state is being furthered by the awards programs of state health departments. Among the states issuing annual awards for well-operated sewage treatment plants is Florida. Annually at the June short course for water and sewage treatment plant operators, the health department presents "best operated" awards to three classes of sewage facilities (primary, trickling filter, and activated sludge) in two population classes: over 10,000 and under 10,000 persons. An overall award is given for the best operated plant in any class.

Radio Communication

The use of mobile radio units by public utilities is an accepted day-to-day operation. Gas, electric, and water systems generally use radio communication to dispatch service equipment, and in particular, to handle emergencies, whether they be complaints or service outages.

Radio communication for sewer maintenance operations has come primarily where water and sewage facilities are combined under the operation of one organization. And this is generally true only in the larger population centers. The advantages of radio communication should not be overlooked. Lift station servicing, complaint investigations, and emergency operations are greatly improved, when a system of radio communication is established.

A large operation can usually handle its own communication system. A small or medium size utility operation can effectively share the radio facilities of other municipal departments—police, fire, or public works.

Each sewerage facility is responsible for effective and efficient operation of its own force. To make use of modern methods of communication is an obvious necessity. The time to do so is at hand. Special utility frequencies have been assigned by the Federal Communications Commission for the use of public utilities. In many places these channels have not been used by the local utilities. Unless effective use is made of them, or unless planning is initiated for their use, other groups will petition to have some or all of these channels assigned to them. The air waves are becoming more crowded each day, and unless sewerage utilities make use of their share they will be speechless when the need to communicate is imperative.

Information on the radio channels assigned to utilities may be obtained from the Federal Communications Commission, Washington 25, D. C.

Improved Mortality

In the period 1879–94, the average lifetime was only 34 years for the American wage earner and his family. His life was hard, often tragic.

The child killers—diphtheria, small pox, and scarlet fever—filled churchyards with tiny tombstones. The other

* Editor's Note—The Nebraska Sewage and Industrial Wastes Association was affiliated with the Federation in 1952; it was the youngest Member Association until 1957.

spoilers, pneumonia, typhoid, influenza, tuberculosis and meningitis, added their toll to the total. Child bearing accounted for many deaths among families.

Today the average length of life has reached a new high of 70.2 years, an increase of 4½ years since 1946, 10 years since 1936, and 24 years since 1909. Women lead with a longevity of 73.6 years; men have an expectancy of 67.3 years.

Our health today is much better than in the "good old days"; let us keep it that way.

Citizens' Bond Campaign *

A mayor-appointed citizens' committee, aided by a staff of city employees, conducted such an effective friend-to-friend public appeal program that Richmond, Calif., approved an $8 million sewer bond issue in December, 1956 by a 7 to 1 majority.

The usual type of campaign was bypassed. Publicity media consisted of digest fact sheets delivered to the voters by block workers, pocket-sized cards highlighting the reasons for a "yes" vote, and daily reminder cards. Building banners, newspaper ads, and bumper strips were used, as well as a limited number of signboards.

Symbol for the campaign was a section of sewer pipe, laid horizontally, with the words "Vote Yes Dec. 11—Sewer Bonds." The symbol appeared in all literature and advertising. A two-column cartoon feature accompanied daily articles on the sewer project in the local press. Featured in the cartoon was a staff-drawn character called "Monsewer," who was merely the sewer pipe symbol with a head, legs and arms. The cartoons were used to stress the most important needs for the "yes" vote.

* Howell, E. S., "Organized City Campaign Helped Put Over $8 Million Richmond Sewer Bond Issue." *Western City*, **33**, 10, 56 (1957).

Some of the lessons learned during the campaign were:

1. Make a careful selection of a representative citizens' committee.
2. Organize the committee to systematically cover every aspect of community life.
3. Don't underestimate the value of staff aid to the committee.
4. Set up a sensitive reporting system to get at misunderstandings that might become issues; follow up with offsetting constructive publicity.
5. Know where the "yes" votes are and get them out to vote.
6. When preparing to sell the bonds, don't assume the financial world knows all about the city; tell them with a brochure; show them with a tour.
7. Thank your citizens for doing a good job; bond issues draw the citizens together. Try to establish a good community feeling; then maintain it.

Death in a Sewage Pumping Station

Death again stalked through a sewage works facility and claimed the lives of two men who were testing equipment of a sewage pumping station in Evansville, Ind., early in September. Fatally overcome were Louis Duncan, superintendent of sewers for Evansville, and Wayne Kiester, resident engineer for the consulting engineering company.

Although the cause of death is not officially known, having been claimed to be "black damp" or "a gas of unknown origin," it probably was asphyxiation with carbon dioxide or poisoning with hydrogen sulfide. Also overcome by the gas were 11 persons aiding in rescue work, all of whom subsequently recovered.

Caution must be exercised at all times at works handling sewage. The newness of a unit does not make it any safer or less death-dealing. Be trained for safety—don't be an "also ran" in a rescue attempt. Know what to do!

Reviews and Abstracts*

Studies on Polysaccharide Formation by *Pseudomonas Fluorescens*. By R. G. Eagon. *Can. Jour. Microbiol.*, **2**, 7, 673 (1956).

Pseudomonas fluorescens produced only mannan, regardless of the type of carbon source employed as nutrient. Stationary cultures were more favorable for polysaccharide formation than shaken cultures. Polysaccharide formation took place after the phase of logarithmic growth.

H. Heukelekian

Extracellular Polysaccharides of Green Algae. By R. A. Lewin. *Can. Jour. Microbiol.*, **2**, 7, 665 (1956).

Uncellular or colonial algae (mostly *Chamydomonas species*) were isolated from soil or fresh water and grown in mass culture. All species liberated some soluble polysaccharide into the growth medium. This material constituted about 25 per cent of the total organic matter produced by the cells. In all but one species, galactose and arabinose were the main components of the polysaccharides. The production of polysaccharides paralleled cell multiplication. Cells, even in the intact state, may liberate colloidal material in the form of mucilaginous sheaths that flow away. Membranes may thus be cast off and soluble substances may result from their solution.

H. Heukelekian

Poliomyelitis and Other Enteric Viruses in Sewages. By S. Kelly, J. Winsser, and W. Winklestein, Jr. *Amer. Jour. Pub. Health*, **47**, 1, 72 (1957).

In an investigation into virus culture methods and relationships between incidence of paralytic disease, socio-economic levels, and virus presence in sewage, 308 sewage samples were analyzed in New York state. The samples were collected by suspending cheesecloth swabs in flowing sewage for two or seven days. They were then prepared and inoculated into mice and kidney tissue. Poliomyelitis viruses were found in 21 per cent of the samples; Coxsackie viruses in 42 per cent; both poliomyelitis and Coxsackie viruses in 13 per cent; and unidentified agents in 3 per cent. Both poliomyelitis and Coxsackie viruses were found seasonally, from early summer to late fall, in the one-year sampling period. However, analysis of the data showed no correlation between the three epidemiological factors cited above.

Coxsackie A viruses were isolated in mice only, poliomyelitis viruses in tissue culture only, and Coxsackie B viruses about equally in mice and tissue cultures. The Coxsackie B viruses were isolated more frequently in monkey kidney tissue than in HeLa cell cultures.

Gilbert V. Levin

Accidental Contamination of a Water Supply by Phenols. By Juliusz Jarocki. *Gas. Woda i Tech. San.*, **31**, 1, 13 (Jan., 1957).

An account is given of the accidental contamination of a water supply by phenols leached from wooden shoring materials. The source of supply is an artificial infiltration gallery. During recent construction of a collecting basin, wooden materials inpregnated with a phenol-containing compound (Xylamit P.P. Extra) were used for shoring. A distinct phenolic taste in the water was observed following a period of heavy rainfall and contact with melted snows. Analysis indicated a concentration of 0.07 mg. per liter phenol as C_6H_5OH in the raw water and 0.04 mg. per liter phenol as C_6H_5OH in the finished water. The source was identified as indicated.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 4435 Wisconsin Ave., N.W., Washington 16, D. C.

The author recommends that compounds used for the waterproofing and protection of wood against fungus growths be treated with non-phenolic-containing compounds where such materials are to be used in connection with water works construction, particularly where direct contact can occur between the water supply source and the construction materials.

CONRAD P. STRAUB

Recovery of Cyanide from Waste Cyanide Solutions by Ion Exchange. By E. GOLDBLATT. *Ind. and Eng. Chem.*, 48, 12, 2107 (1956).

This article deals with laboratory studies of the use of a strong-base ion exchange resin for the removal of cyanide ions from a waste stream. The resin is first charged with cuprous ion, with which the cyanide ions complex. The spent column is scrubbed with 0.02N sulfuric acid as an eluent for removing the cyanide from the complex without removing the copper. Thiocyanide ions interfere in the recovery of either cyanide or water but it is hoped to use both for the plant-scale application.

R. S. INGOLS

Stream Standards vs. Effluent Standards. By W. B. HART. *Ind. and Eng. Chem.*, 48, 11, 47A (1956).

This article is a plea by an industrialist to use stream standards in place of effluent standards for pollution control.

R. S. INGOLS

Symposium: Re-Use of Water by Industry

I. Introduction. By S. K. LOVE. *Ind. and Eng. Chem.*, 48, 12, 2145 (1956).

In 1950 industry was responsible for 35 per cent of the nation's use of water. For 1975 the forecast indicates that it will use 63 per cent of a greater total. To extend the limited resources of water, industrial re-use must be expanded.

II. Re-Use of Steam Condensate as Boiler Feedwater. By D. E. NOLL AND H. M. RIVERS. *Ind. and Eng. Chem.*, 48, 12, 2146 (1956).

A very complete review of the factors necessary for consideration in the re-use of steam condensate as boiler feedwater.

III. Conservation of Water in the Pulp and Paper Industry. By H. B. BROWN. *Ind. and Eng. Chem.*, 48, 12, 2151 (1956).

A step-by-step review of the manufacture of pulp and paper is presented with an indication of what can be done in a paper plant to reduce water use.

IV. Recirculation of Cooling Water in Petroleum Refining. By A. J. BRANDEL. *Ind. and Eng. Chem.*, 48, 12, 2156 (1956).

A review of the means by which one petroleum plant recirculates its cooling water.

V. Re-Use of Cooling Water in Atomic Energy Installations. By A. L. BILADEAU. *Ind. and Eng. Chem.*, 48, 12, 2159 (1956).

The water used for cooling aluminum-clad fuel elements in an atomic power generator must be of the highest purity. When the total solids exceeds 0.5 mg. per liter of cooling water, the radioactivity of the solids becomes intense enough to require shielding of the water system for personnel protection. Some of this primary cooling water is continuously circulated through two-bed ion exchange units. When these units are exhausted, they are sufficiently radioactive to require discard by burial.

VI. Biological Fouling in Recirculating Cooling Water Systems. By J. J. MAGUIRE. *Ind. and Eng. Chem.*, 48, 12, 2162 (1956).

Cooling is the consumer of the largest volume of water; therefore, recirculation is frequently used to reduce waste-water volume. However, evaporation of water permits the concentration of all of the elements favoring growth of the biological slimes of algae and fungi. Because metal and wood protection generally require water conditions otherwise favorable to microorganisms, it is frequently necessary to use one or more chemicals, including chlorine, bromine, chlorinated phenols, copper salts, and quaternary ammonium compounds to maintain a desirable heat transfer condition.

VII. Adaptation of Treated Sewage for Industrial Use. By S. T. POWELL. *Ind. and Eng. Chem.*, 48, 12, 2168 (1956).

This paper reviews some of the many successful industrial uses of sewage plant

effluents. This procedure would appear to be an excellent answer to a growing water shortage and one which permits all parties to benefit.

R. S. INGOLS

***Ferrobacillus Ferrooxidans:* A Chemosynthetic Autotrophic Bacterium.** By W. W. LEATHEN, N. A. KINSEL, AND S. A. BRALEY. *Jour. Bact.*, 72, 700 (1956).

A chemosynthetic autotroph was isolated from bituminous coal mine effluents and designated as *Ferrobacillus ferrooxidans*. It does not grow on usual bacteriological media. Carbohydrate and peptone inhibit the oxidizing ability of the microorganism. It oxidizes ferrous iron to the ferric state within a pH range of 2.0 to 4.5. At this pH value, chemical oxidation of ferrous iron is extremely slow; 200 p.p.m. of Fe^{++} is oxidized to Fe^{+++} in three days by this organism while sterile Fe^{++} solution requires more than two years to be completely oxidized. The official pH for this organism is 3.5 and the temperature is 20° to 25° C. The organism utilizes CO_2 from air and NH_3-N as a source of N. Elemental sulfur is not oxidized.

Pyrite found in coal is oxidized on exposure to the atmosphere without bacterial intervention, producing ferrous sulfate and H_2SO_4. Water seeping into a mine leaches the soluble oxidation products from the exposed surfaces. Accelerated by *Ferrobacillus ferrooxidans*, ferrous sulfate is rapidly oxidized to ferric sulfate and eventually all of the ferrous sulfate is oxidized to ferric sulfate. Ferric sulfate is hydrolyzed to insoluble ferric sulfate, ferric hydroxide, and sulfuric acid. The insoluble iron compound deposits as a yellowish sludge in the stream while the stream remains acid.

H. HEUKELEKIAN

Pollution of the Vistula River at Jabonna. By H. WYSOCKA, M. TOMASZEWSKA, K. CZYŻ, AND A. PRASZKIEWICZ. *Gaz. Woda i Tech. San.* (Polish), 30, 9, 359 (Sept., 1956).

Preliminary biological findings show that the Vistula River in the vicinity of Jabonna shows evidence of pollution from pharmaceutical and tannery effluents discharged into the Henrykowski Canal. Twenty specific groups of organisms were reported in the Vistula upstream of the canal; only four groups in the canal with *Ascomycetes non det.* predominant; 20 groups 20 meters (m.) below the confluence of the canal; 23 groups 250 m. below, and 19 groups 1,000 m. below. Organisms belonging to the β. mesosaprobic groups predominated at 250 and 1,000 m. below the confluence and also above the confluence of the canal.

CONRAD P. STRAUB

Salinity and the Biochemical Oxygen Demand of Estuary Water. By J. GRINDBY AND A. B. WHEATLAND. *Water and San. Engr.* (Brit.), 6, 1, 10 (1956).

Maximum B.O.D. values were found when the salinity of the diluted sample was 20 g. per 1,000 g. of estuary water. When the salinity of the original sample was greater than 14 g. per 1,000 g., the B.O.D. was slightly higher when saline dilution water was used to give approximately the same salinity as the original sample. When the salinity of samples was less than 14 g. per 1,000 g., higher B.O.D. values were obtained with standard dilution water.

The onset of nitrification was retarded with increasing salinity. The total amount of oxygen utilized after 67 days, however, was practically the same with different salinities.

H. HEUKELEKIAN

Recent Trends in the Analysis of Industrial Wastes. By W. A. MOORE AND M. B. ETTINGER. *Anal. Chem.*, 28, 1819 (1956).

The article is a review of the important problems in industrial waste disposal and of research work in progress in the Public Health Service laboratory.

R. S. INGOLS

Determination of Trace Amounts of Alkyl Benzene Sulfonates in Water. By P. J. WEAVER. *Anal. Chem.*, 28, 1822 (1956).

The article gives a complete set of directions for the identification and quantitative determination of alkyl benzene sulfonates (common synthetic detergents) in water. The steps include absorption on carbon, desorption, removal of interferences, and reaction with an amine for extraction in chloroform which is used for infra-red examination.

R. S. INGOLS

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4 SUPERIOR FEATURES

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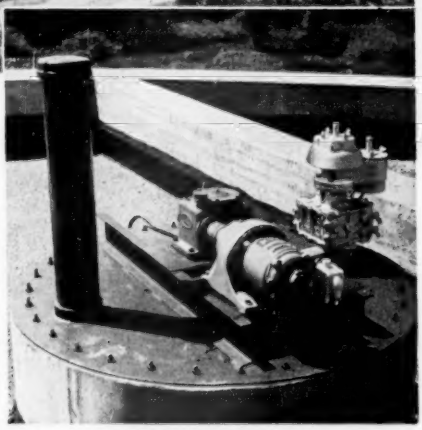
PRESSURE RELIEF and VACUUM BREAKER VALVE with FLAME ARRESTER

FIG. No. 5800C



"VAREC" Fig. No. 5800C
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1. The multi-plate Flame Arrester bank has larger area than competitive units of same size.

2. Much more flow per minute than same size competitive equipment, due to less capillarity and friction in the Flame Arrester passageways; streamlining and expanding passageways of Pressure Relief and Vacuum Breaker Valve.

3. Easy to clean. Just loosen frame holding Flame Arrester plates together — plates separate to permit easy cleaning with distillate, chemical solution or wire brush.

4. All aluminum construction makes "VAREC" Pressure Relief and Vacuum Breaker Valve corrosion resistant. Lighter weight facilitates installation.

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Proceedings of Member Associations

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 42nd Annual Meeting of the New Jersey Sewage and Industrial Wastes Association was held at the Hotel Traymore, Atlantic City, N. J., on March 13–15, 1957. Registration totaled 505, including 70 women. This was a new high in attendance, which usually averages about 425.

Newly featured at the meeting was the scheduling of the first day as a full day on industrial waste papers. Attendance was good and reportedly contributed materially to the increase in registration.

Making up the industrial waste portion of the program were papers on anthroquinone dye wastes, paper mill effluents, synthetic organic chemical waste pollution, plant site selection, and industrial wastes effects on water supplies. Papers were also presented on sludge dewatering, sludge disposal by barging, lift stations, plant operation, Public Law 660, use of sewage for crop irrigation in Israel, and contact aeration sewage plants in New Jersey.

Constitution changes of the New Jersey Association were discussed at the annual business meeting. The Bedell nominee for 1957 is Louis J. Fontenelli, Supervising Engineer, Rahway Valley Joint Meeting. The Hatfield nominee is Anthony J. Macri, Superintendent, Hammonton, N. J., Sewage Treatment Plant.

(*Continued on page 534a*)

SNOW GATES

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HARVEY, ILLINOIS ENDS PROBLEM OF FLOODED BASEMENTS WITH

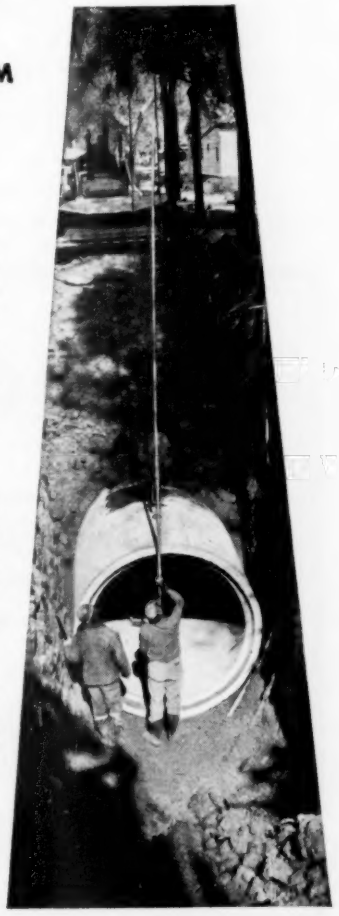
CONCRETE PIPE

To end a vexing problem of flooded basements in a large section of the city, Harvey, Ill. built a new relief concrete pipe storm and sanitary sewer. Both the old and the new sewer lines connect with the system of the Chicago Sanitary District at the north city limits.

The project used more than 40,000 ft. of concrete pipe 21 to 90 in. in diameter. It was financed by two bond issues—$675,000 in revenue bonds and $1,500,000 in general obligation bonds.

Like Harvey, hundreds of American cities depend on long-lasting concrete pipe sewer installations. These many systems have demonstrated concrete pipe's rugged durability, great structural strength, maximum hydraulic capacity, minimum infiltration and leakage, and unusual resistance to abrasion.

Concrete pipe sewers are moderate in first cost, require little maintenance and give lifetime service. The result is true ***low-annual-cost*** sewer service. Write for free 48-page booklet, *"Concrete Sewers,"* distributed only in the United States and Canada.



PORTLAND CEMENT ASSOCIATION
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A national organization to improve and extend the uses of portland cement and concrete . . . through scientific research and engineering field work

The following officers were elected:

President: Andrew Palmer, Dunellen.
First Vice-President: Robert J. Budrick, Boonton.
Secretary-Treasurer: Michael S. Kachorsky, Manville.

MICHAEL S. KACHORSKY,
Secretary-Treasurer

MONTANA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The Montana Sewage and Industrial Wastes Association held its 13th Annual Meeting in conjunction with the annual meeting of the Montana Section, American Water Works Association on April 4–6, 1957 at Great Falls, Mont.

Approximately 125 members, guests, and ladies were registered. This was the first joint program of the two associations. The blended program of water and sewage interests was well received by operating personnel who frequently have the dual responsibility of the water and sewage utility.

An interesting program event was a symposium on waste disposal, which featured the basic industries of Montana—ore, oil, sugar beets, and pulp.

Federation Past President George W. Martin presented the Bedell Award in absentia to Rodney Preater, Sanitary Engineer, Morrison Maierle Inc., Helena, Mont. A program highlight was the luncheon and tour of the Malmstrom Air Force Base, Strategic Air Command, U. S. Air Force.

Officers elected for 1956–57 were:

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(*Continued on page 536a*)

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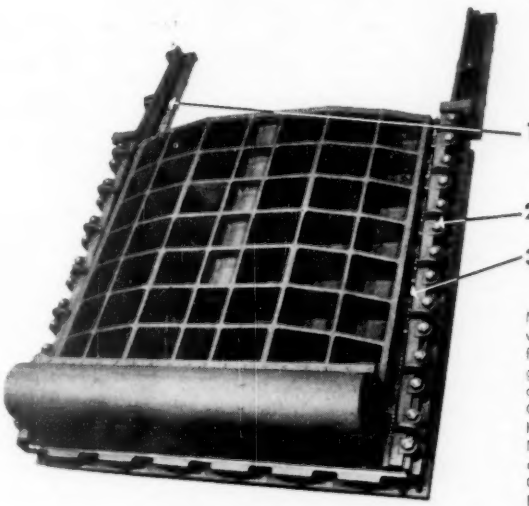

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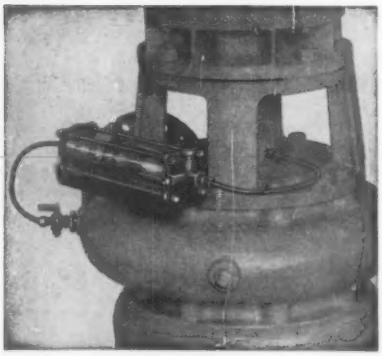

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Correction

The proceedings of the Ohio Sewage and Industrial Wastes Treatment Conference appearing on page 446a of the October issue of THIS JOURNAL inadvertently contained a mixup in the names of the recipients of awards presented at the 1957 Annual Meeting of the Conference. The correct recipients are:

Bedell Award — Bruce M. McDill, Ohio Department of Health.

Hatfield Award — Arthur Caster, City of Cincinnati.

In addition, Ohio Conference awards were made as follows:

Dean Stewart Award — Willard Smith, Cambridge.

J. W. Ellms Award—Arthur Caster, Cincinnati.

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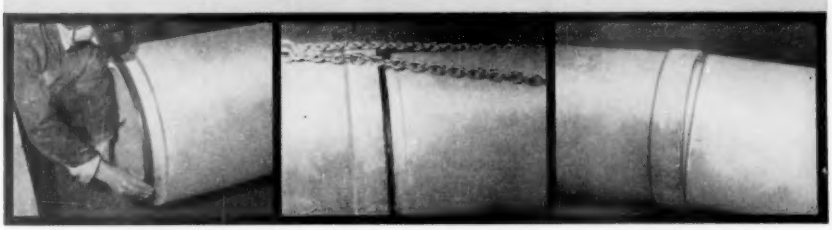

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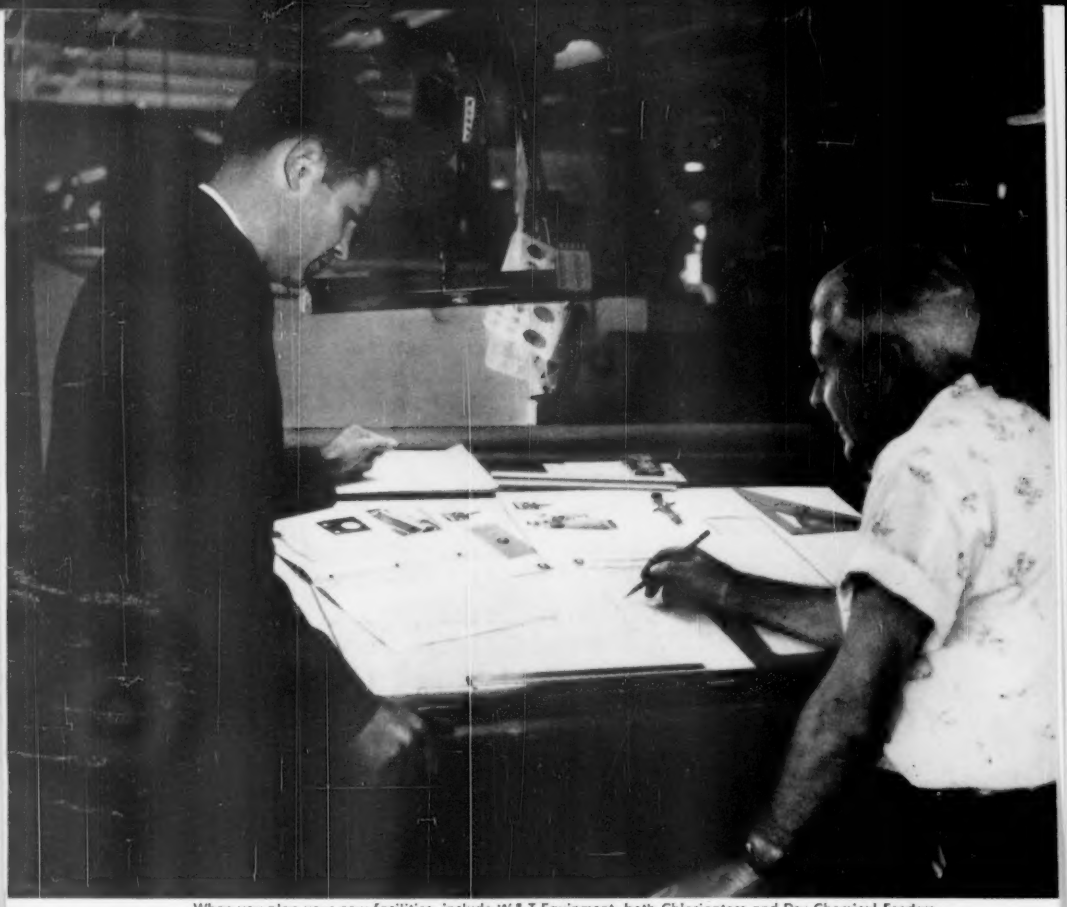

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